Sorensen

DCRA SERIES

800-WATT

POWER SUPPLIES

DCR 40-20A

Instruction Manual

PERSONNEL SAFETY NOTICE

Voltages ranging up to 300Vdc (depending on model) are across the unit output terminals both front and rear. Follow operating procedures exactly. Do not make terminal board nor load terminal alterations with unit ON. Advise all operating personnel of the presence of injurious or possibly fatal voltages.

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[illegible] service is performed at Sorensen during the weekday hours of 7:30 am to 4:30 pm Pacific [illegible]epair work requested to be accomplished outside of normal working hours will be subject to [illegible]arranty service rates.

[illegible]ervice is available on an emergency basis. Travel expenses (travel time, per diem expense, [illegible]are) are the responsibility of the Buyer. A Buyer purchase order is required by Sorensen [illegible]ing.

[illegible]uct found, upon inspection by Sorensen, to be in specification is subject to an inspection fee [illegible]freight charges.

[illegible]hased in the United States carries only a United States warranty for which repair must be [illegible] the Sorensen factory.

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TABLE OF CONTENTS

Page No.

Section I. Introduction and Description

- Introduction 1-1
- Description 1-1
  - Automatic Crossover 1-1
  - Remote Sensing 1-1
  - Series Operation 1-1
  - Parallel Operation 1-1
  - Remote Programming 1-4
  - Protection Features 1-4
- Optional Modification 1-4

Section II. Preparation for Use

- General 2-1
- Initial Inspection 2-1
- Electrical Installation 2-1
  - Input Terminal Board 2-1
- Mechanical Installation 2-1
- Initial Checkout 2-1
  - Voltage Mode 2-1
  - Current Mode 2-2

Section III. Operating Instructions

- General 3-1
- Personnel Safety 3-1
- Operating Precautions 3-1
- Voltage - Mode Operation 3-1
  - Local Sensing 3-1
  - Remote Sensing 3-2
  - Remote - Sensing Recalibration 3-3
  - Resistance Programming 3-3
  - Precision Calibration 3-4
  - Signal Programming 3-4
  - Alternate Programming Methods 3-4
- Current - Mode Operation 3-4
  - Resistance Programming 3-5
  - Signal Programming 3-5
  - Alternate Programming Methods 3-5
- Parallel Operation 3-5
  - Master-Slave Paralleling 3-6
  - Direct Paralleling 3-6
- Series Operation 3-7
  - Rectifier Recommendations 3-7

No. Page No.

Section IV. Principles of Operation

Introduction........ 4-1
Phase - Control Principle........ 4-1
Block - Diagram Discussion........ 4-1
Reference Supply........ 4-1
Voltage - Mode Section........ 4-4
Current - Mode Section........ 4-4
Sawtooth - Generator Section........ 4-4
Mixer Section........ 4-5
Multivibrator Section........ 4-5
Inverter and Switch Section........ 4-5
Firing Section........ 4-5
Synchronizing Section........ 4-5
Power Section........ 4-6
Thermal Overload........ 4-6

Section V. Maintenance

General........ 5-1
Periodic Servicing........ 5-1
Troubleshooting........ 5-1
Calibration........ 5-1
Reference - Power Supply........ 5-1
Voltage - Mode Section........ 5-1
Current - Mode Section........ 5-3
Performance Testing........ 5-10
Voltage - Mode Regulation and Ripple........ 5-10
Transient Response........ 5-11
Current - Mode Regulation........ 5-11

Section VI. Replacement Parts List

General........ 6-1
Manufacturer Coding........ 6-1
Modification Models........ 6-1
Ordering Parts........ 6-1

LIST OF ILLUSTRATIONS

Title	Page No.
Current Derating Characteristics	1-4
Crossover Characteristics	1-4
Typical Output Impedance, 40-20A	1-5
Typical Output Impedance, 80-10A	1-5
Typical Output Impedance, 300-2.5A	1-5
Typical Output Impedance, 60-13A	1-5
Typical Output Impedance, 150-5A	1-5
Controls and Indicators	3-1
Remote Sensing Hookup	3-3
Voltage Mode Prog. Hookup	3-3
Current Mode Prog. Hookup	3-5
Master-Slave Parallel Hookup	3-6
Direct Parallel Hookup	3-6
Series Operation	3-7
Phase Control Firing Angles	4-1
Block Diagram	4-2
Effects of High and Low Signals on Firing Angle	4-3
Typical Component Board	5-4
Typical Partial Disassembly	5-5
Selected Signal Traces	5-6
Schematic Diagram	5-7/8
Performance Test Setup	5-9

LIST OF TABLES

Title	Page No.
ecifications (Sheet 1 of 2)	1-2
(Sheet 2 of 2)	1-3
izes, Current - Mode Check	2-2
ls and Indicators	3-2
mended Rectifiers, Series Operation	3-7
shooting Data (Sheet 1 of 2)	5-2
(Sheet 2 of 2)	5-3
tion Data	5-9
ance Test Data	5-10
ment Parts List (Sheet 1 of 5)	6-2
(Sheet 2 of 5)	6-3
(Sheet 3 of 5)	6-4
(Sheet 4 of 5)	6-5
(Sheet 5 of 5)	6-6
ce Parts List, Modified Units	6-6

SECTION I

INTRODUCTION AND DESCRIPTION

… ins operation and mainte-
… DCRA Series power sup-
… theon Company, Sorensen
… cticut. It is intended to
… functioning of the unit,
… ications for which the
… furnish sufficient mainte-
… perating life. Note that
… defines a set of Models
… A, 60-13A, 80-10A

… form the manual divisions.
… ion of the units, a tabu-
… specifications, and a set
… etails on initial inspec-
… es are given in Section
… including methods for
… pplications, comprise
… V provide the principles
… procedures, respec-
… list forms Section VI.

… bench or rack use, a
… er supply provides highly
… ut, adjustable over a wide
… ominal 115 Vac (or 220/
… exhibits a rapid response
… line. Highly efficient, it
… merous applications. For
… cations, refer to Table

… used in the DCRA cir-
… contribute significantly
… emperature range charac-
… ransistors and diodes are
… ircuit board while high-
… sinked to aluminum
… n.

… num front panel mounts all
… ed under normal conditions.
… ker, FINE and COARSE
… rs, and a CUR. ADJUST

AMPS. control. In addition, the front panel mounts a set of binding posts from which the unit output may be taken. (The output also appears across a pair of terminals located on the rear terminal board.)

1-8. AUTOMATIC CROSSOVER. There are two basic operating modes, voltage and current. In the former, the voltage is held constant while the current varies with the load. In the current mode, on the other hand, the voltage varies, and current is held constant. The automatic crossover feature enables the unit to transfer operating modes as a function of load requirements. If, for example, load current attempts to increase above the current limit set on the cur. adjust amps control, the unit will switch operation automatically from the voltage to current mode. In this mode, the current will be regulated at the front-panel selected value. If load requirements are lowered, return to the voltage-regulating mode will occur automatically. A green lamp on the front panel glows to indicate the current-mode operation. Figure 1-2 illustrates typical crossover characteristics. In the expanded knee, multiple curves depict the ambient-temperature effects.

1-9. REMOTE SENSING. Terminals located on the rear-mounted terminal board offer the means of extending a unit's regulating point from the output terminals to the load. This, in effect, compensates for variations in the load lead IR drop. The maximum drop for which a unit will compensate is 8 volts per load lead.

1-10. SERIES OPERATION. For applications requiring output voltages higher than a single unit can provide, DCRA's may be connected in series. Table 1-1 lists the number of units which may be series connected for each Model. Regulation in series operation is the sum of the regulations for all units.

1-11. PARALLEL OPERATION. Parallel operation may be used to service those applications requiring an output current higher than a single DCRA can provide. Using a "master-slave" approach, a maximum of 4 units may be connected in parallel. However, the output current of each unit must be derated by 90%. An alternate method is direct paralleling. With this approach, there is no limit to the number of units which can be paralleled nor is there any current derating.

Coefficient, approximate		7.5Ω/A	11.5 Ω/A	15 Ω/A	30 Ω/A	60 Ω/A
Crossover Characteristics	See Fig.1-2					
Transient Response[9]						
Output Volt. Deviation Vdc		1.2	1.8	2.4	4.5	9
Typical Recovery	30 msec					
Output Voltage Overshoots						
Turn-off	None					
Turn-on		None above 5 V, 0.3 V below 5 V.	None above 7 V, 0.4 V below 7 V.	None above 10 V, 0.5 V below 10 V.	None above 25 V, 1V below 25 V.	None above 50 V, 2 V below 50 V.
Ambient-Temperature Range	0 - 71°C	See Figure 1-1 for Derating Characteristics				
Output Impedance		Fig. 1-3	Fig. 1-6	Fig. 1-4	Fig. 1-7	Fig. 1-5
Stability (typ)[10]						
Voltage Mode	.05% E_o max.					
Current Mode	.15% I_o max.					
Max. Number of Units in Series		5	4	4	2	2
Max. Number of Units in Parallel	4	Derate each unit to 90% I_o max.				
Remote Sense Compensation	8 V/load lead					
Cooling	Forced Air					
RFI Characteristics (typ)	Meets or surpasses requirements of Mil-I-26600 and Mil-I-6181					
ENVELOPE DIMENSIONS						
Width in.	19 rack, 19-1/2 selfcont.					
Height in.	5-1/4 rack					
Depth in.	18					
WEIGHT lb.	77					

NOTES

(6) The dynamic voltage range may be increased to Eo max. At no-load, set the output voltage (at front panel control or by internal adjustment) to 1.07 Eo max. The new value of Eo max. = 1.07 Eo max.

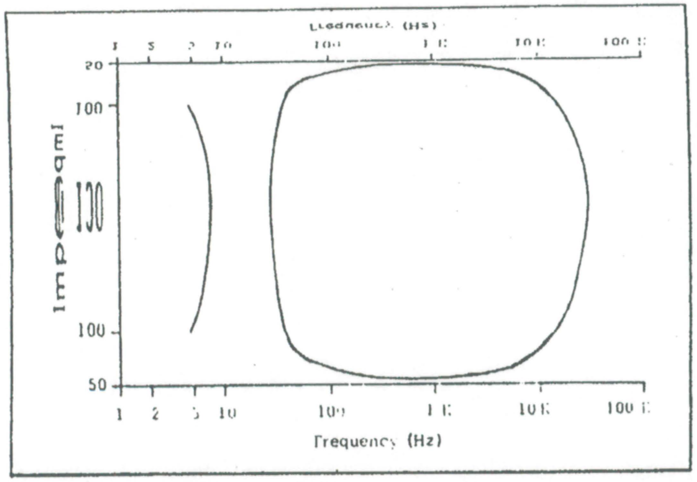
(7) For combined load and line, and full dynamic voltage change.

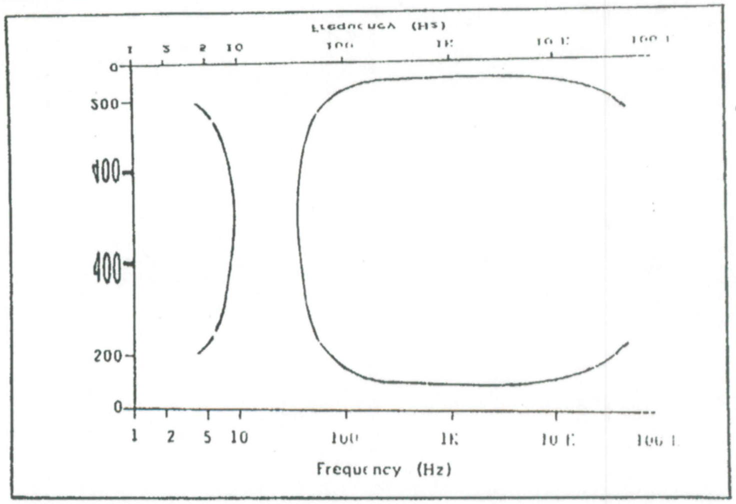
(8) Specification applies at short circuit. For compliance voltages from full compliance voltage (Ecmax.) to .15E_c max., ripple current varies from 0.5% to 1% Io.

(9) For a step-load change, half-load to full-load or full-load to half-load, and recovery to within ±1% band.

(10) 8 hours after warm-up and with constant line, load and ambient temperature.

Table 1-1. Unit Specifications (Sheet 2 of 2)





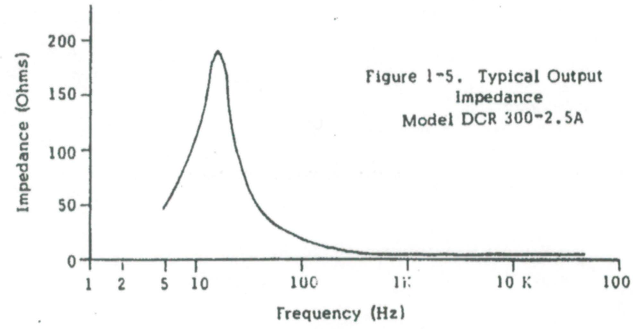


Figure 1-5. Typical Output Impedance Model DCR 300-2.5A

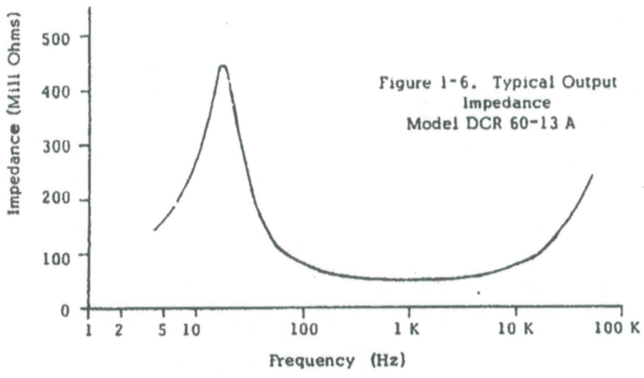


Figure 1-6. Typical Output Impedance Model DCR 60-13 A

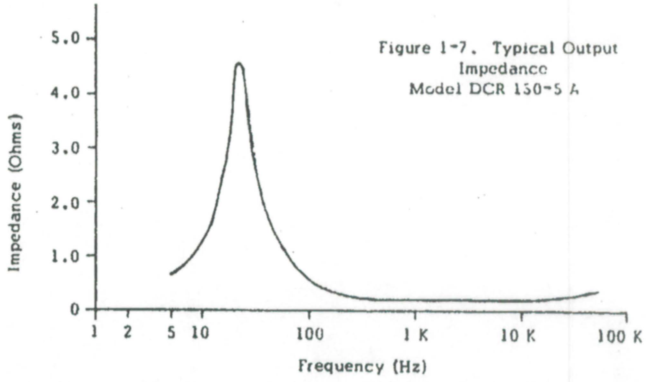


Figure 1-7. Typical Output Impedance Model DCR 150-5 A

SECTION II

PREPARATION FOR USE

2-1. GENERAL.

2-2. After unpacking, initial inspections and preliminary checkout procedures should be performed to assure that the unit is in good working order. Basically, these consist of visually checking for damaged parts and components, and making an electrical check. If it is determined that the unit is damaged, follow the instructions on the Damage and/or Loss in Shipment form enclosed with the unit, and notify the carrier immediately. The carrier's claim agent will then prepare a report of damage. The user is required to send this report to the Service Dept., Raytheon Company, Sorensen Operation, Richards Avenue, Norwalk, Conn. Sorensen will, in turn, advise the user as to what action is required to repair or replace the supply.

2-3. INITIAL INSPECTION.

2-4. Proceed as follows to inspect for damage incurred during shipment.

a. Inspect panel and chassis for scratches, dents and chips.

b. Turn front-panel voltage and current controls from stop-to-stop. Rotation should be smooth through a 300-degree angle.

c. Check meter faces for cracked or broken windows. Check each meter pointer for zero indication. If necessary, use adjust screw to bring indicator to zero.

d. Look for cracked or broken lenses on indicating lights.

e. Alternate circuit breaker between ON and OFF a few times. Action should be both positive and audible. Terminate check with breaker in OFF position.

f. Remove rear cover, and check terminal board. Make sure that links are firmly in place across terminals 1-2, 4-5, 6-7, 8-9, and 10-11.

g. Remove top-cover retaining screws. Inspect components and printed-circuit board for damage.

Note

Modified units are shipped ready for use with a 220-Vac input. If a 230-Vac input is to be used, refer to para 2-6 before remounting cover.

2-5. ELECTRICAL INSTALLATION.

2-6. Standard 800-Watt-Series units are shipped ready for use with a nominal 115-Vac input, and modified units will accept a 220-Vac input. If it is desired to use a 230-Vac input with modified units, disconnect wire at tap 4 of transformer T2, and reconnect at tap 3.

2-7. INPUT TERMINAL BOARD. A three-terminal, barrier-type board is provided at unit rear for input corrections. The board will accept a maximum of No. 10 solid copper wire. Connect input wires, grounding at center terminal. Use a cable strain-relief at rear access cover.

2-8. MECHANICAL INSTALLATION.

2-9. As received, an 800-Watt-Series unit is ready for bench use. To adapt for rack mounting, simply invert unit, remove feet and reinstall feet-retaining screws.

2-10. INITIAL CHECKOUT.

2-11. VOLTAGE MODE. To check voltage-mode operation, proceed as follows:

a. Insert input power plug into a suitable receptable.

b. Turn COARSE and FINE VOLTAGE ADJUST controls fully counterclockwise, and CUR. ADJUST AMPS. control almost to zero.

c. Set unit circuit breaker to ON with zero load current.

d. Turn COARSE VOLTAGE ADJUST control slowly clockwise while observing unit voltmeter. [illegible]er should swing upscale.

e. With pointer at half-scale, rotate the FINE VOLTAGE ADJUST control from stop-to-stop. Range should be as indicated in Table 1-1 under Voltage Mode.

f. Set unit circuit breaker to OFF.

2-12. CURRENT MODE. To check unit operation in the current mode, proceed as follows:

a. Turn FINE and COARSE VOLTAGE ADJUST and CUR. ADJUST AMPS. controls fully counterclockwise.

b. Connect a 0-1 Vdc voltmeter across front panel output terminals.

c. Set unit circuit breaker to ON and rotate FINE VOLTAGE ADJUST control slightly clockwise or until about 0.2 volts are indicated on voltmeter.

d. Set circuit breaker to OFF and disconnect voltmeter.

e. Connect about 4 feet of copper wire across the output terminals. Wire sizes are listed by model in Table 2-1.

f. Set circuit breaker to ON. CURRENT MODE indicator glows.

g. In steps using small increments, rotate CUR. ADJUST AMPS. control clockwise while observing unit ammeter. Control setting should correspond with current indicated by unit ammeter.

h. Set circuit breaker to OFF.

i. Remove shorting wire from terminals.

DCR MODEL	WIRE SIZE
40-20A	No. 14
60-13A	No. 16
80-10A	No. 18
150-5A	No. 20
300-2.5A	No. 24

Table 2-1. Wire Sizes, Current-Mode Check.

SECTION III
OPERATING INSTRUCTIONS

3-1. GENERAL.

3-2. This section, in addition to providing basic operating instructions, details the methods by which units in the 800-Watt-Series may be adapted to their more common applications, including remote sensing, remote programming, and series and parallel operation. Table 3-1 lists each operating control and indicator and its function, and Figure 3-1 shows the controls and instruments. Refer to para 3-3 before operating unit.

3-3. PERSONNEL SAFETY.

3-4. Voltages ranging to 300 Vdc (depending on the model) appear across unit output terminals both front and rear. Follow operating procedures exactly. Do not make terminal board nor load-terminal alterations with unit ON. Advise all operating personnel of the presence of injurious or possibly fatal voltages.

3-5. OPERATING PRECAUTIONS.

3-6. High voltage output (which may damage the load or injure personnel) and loss of current limiting (which may result in a damaged unit) can result from loosening or removing links on the rear-mounted terminal board. Do not remove nor loosen any links unless specifically instructed to in subsequent procedures.

3-7. VOLTAGE-MODE OPERATION.

3-8. LOCAL SENSING. The 800-Watt Series units are shipped ready for use in the local-sensing configuration, i.e., with the unit voltage-regulating at the output terminals. This may be undesirable if variations in the load-lead voltage drops are expected to be great in comparison with the unit's specified regulation. To compensate for prohibitive drops, use remote sensing (para 3-10).

3-9. To operate unit in the voltage-mode, local-sensing configuration proceed as follows:

a. Rotate the FINE and COARSE VOLTAGE ADJUST controls (see Figure 3-1) fully counterclockwise, and the CUR. ADJUST AMPS. control almost to zero.

b. Insert input power plug into a suitable receptacle.

c. Set unit circuit breaker to ON. POWER light glows.

d. Rotate COARSE VOLTAGE ADJUST until the unit voltmeter indicates the desired output voltage. Use FINE VOLTAGE ADJUST for small sensitive adjustments.

e. Set unit circuit breaker to OFF.

f. Remove rear cover and connect load lines to terminals 9 and 10. Use knockouts in rear cover to run leads into terminal board.

g. Turn CUR. ADJUST AMPS control to the desired current-limiting value.

Note

To avoid possible loss of regulation when operating near the limit point, set the CUR. ADJUST AMPS. control at least 3% above the desired maximum operating current.

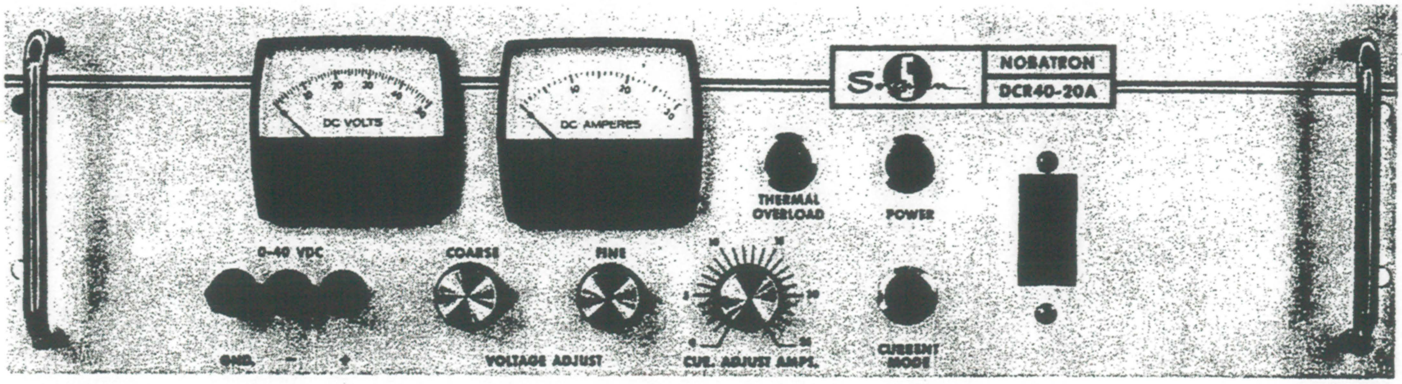


Figure 3-1. Controls and Indicators

Remount cover and set unit circuit breaker to ON. POWER light glows, and the unit is in voltage-mode with local-sensing.

3-10. REMOTE SENSING. A few link changes at the rear panel and alterations at the load terminations of the output leads are all that are required to convert the unit to remote-sensing operation. In this mode, voltage regulation is at the load rather than at the unit output terminals, thus compensating for voltage-drop variations in the load lines.

Note

An 8-volt drop per line is the maximum for which remote sensing will compensate. Voltage across load is equal to voltage output of unit minus line drops.

3-11. To adapt unit for remote-sensing operation, proceed as follows:

a. Recalibrate the current-mode circuit per para. 3-12.

b. With no load on unit, set output voltage to the desired value; then set circuit breaker to OFF.

CONTROL/INDICATOR	FUNCTION
COARSE VOLTAGE ADJUST	A 3k ohm potentiometer across which the reference voltage for voltage-mode operation is developed. Used to adjust the output voltage.
FINE VOLTAGE ADJUST	A 150 ohm potentiometer connected in series with the COARSE VOLTAGE ADJUST potentiometer and used to make small but sensitive variations in the output voltage.
CUR. ADJ. AMPS	A 150 ohm potentiometer used in the first stage of the current mode amplifier to vary the reference and subsequently the output current.
CURRENT MODE Indicator	A green light which, when glowing brightly, indicates that the unit is operating in the current regulating mode.
Unit Circuit Breaker	A 250 V, 25 A, circuit breaker used to connect, or disconnect, incoming power to, or from, the unit, and to protect the unit in event of internal failure.
POWER Indicator	A red light, connected across the primary of transformer (T2), which, when glowing, indicates that the unit circuit breaker is closed.
THERMAL OVERLOAD Indicator	An amber light which when glowing indicates that high internal temperatures have been reached and the unit shut off until temperatures return to normal.
Unit Ammeter	A meter connected in the positive leg of the unit output which indicates output current.
Unit Voltmeter	A meter connected internally across the SENSE terminals of terminal board (TB2) to give an indication of unit voltage output.

Table 3-1. Controls and Indicators

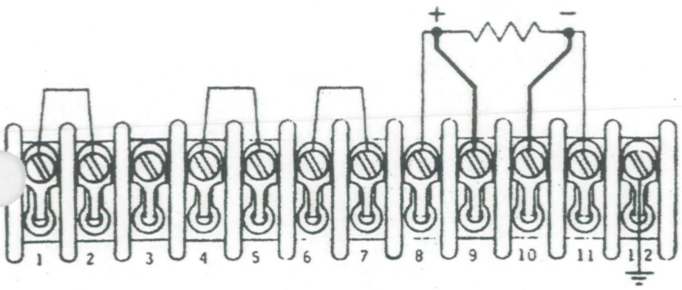


Figure 3-2. Remote Sensing Hookup

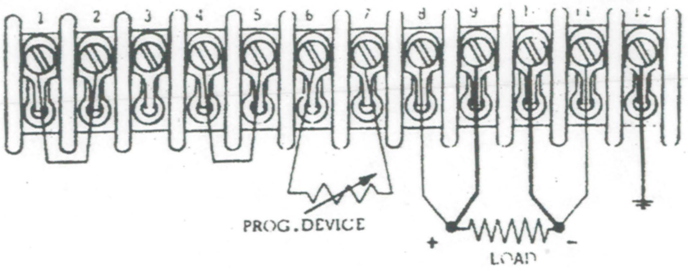


Figure 3-3. Voltage Mode Prog. Hookup

c. Remove rear cover, and disconnect links between terminals 8 and 9, and 10 and 11 (Figure 3-2).

d. Run output leads from load through knockouts in rear cover to terminals 9 and 10. Observe polarity.

e. Connect sensing leads from load to terminals 8 and 11, again observing polarity. To reduce stray pickup, use coaxial cable or a twisted pair of wires for sensing leads.

f. Remount the rear cover and set unit circuit breaker to ON. The unit is now in the voltage-mode with remote-sensing.

3-12. REMOTE-SENSING RECALIBRATION. When a DCRA unit is operated in the remote-sensing mode, the current-mode reference will shift slightly, altering current-mode-circuit calibration by about 5% Io for each volt of negative load-lead drop. As an example of the effect, assume that a DCR 40-20A is supplying A and the negative load-lead drop is one volt. The lting change in voltage-current crossover (limiting) point will be 0.5 A. In other words, the true crossover point will be 0.5 A less than that set on the CUR. ADJUST AMPS. control. If this effect is undesirable, compensate for by (1) using the CUR. ADJUST AMPS. control to raise the crossover point to a new value given by:

$$I_s = I_C \quad (1 + Vrs/20)$$

where: I_s = setting on CUR. ADJUST AMPS.

I_c = desired crossover value

Vrs = voltage drop in negative load lead

or (2) recalibrating the current-mode circuit. This may be done as follows:

a. Remove rear cover.

b. At output terminals, connect load leads. Use leads intended for use in normal operation.

c. Run load leads to a 0.5% tolerance ammeter. Select an ammeter with a current capacity compatible with unit's rated output.

d. Remove link between terminals 10 and 11, and connect a sensing lead from terminal 11 to negative s f meter.

e. Turn CUR. ADJUST AMPS. control fully clockwise.

f. Rotate FINE and COARSE VOLTAGE ADJUST controls fully counterclockwise and then turn FINE control clockwise a few degrees.

g. Turn potentiometer (R32), located near rear terminal board, fully clockwise.

h. Set unit circuit breaker to ON.

i. Rotate potentiometer (R32) slowly counterclockwise until output current, indicated on test ammeter, equals CUR. ADJUST AMPS. setting.

j. Turn CUR. ADJUST AMPS. control fully counterclockwise. Output shoud be 0 ± .1 A. If necessary, adjust using potentiometer R30.

k. Rotate CUR. ADJUST AMPS. control fully clockwise. Ammeter should indicate same output current as obtained in step i. If it does not, readjust current using R32.

l. Repeat steps j and k until high and low settings are as specified.

m. Set unit circuit breaker to OFF before disconnecting test set-up.

3-13. RESISTANCE PROGRAMMING. The output voltage of any model in the 800-Watt-Series may be controlled from remote locations by connecting a resistance (fixed or variable) into the voltage-mode-amplifier reference circuit. Terminals on the rear terminal board are provided for this purpose.

3-14. The ohms/volt coefficient for each model in the 800-Watt-Series is listed in Table 1-1. The values tabulated are approximate, with the actual values somewhere within ± 10% range of those given. (If a more precise value is desired, refer to para 3-16 for calibration procedures.) In selecting a programming resistor, choose one with a low temperature coefficient (± 30 ppm) and a wattage rating at least 10 times that calculated. Programming current is about 3 mA. If step changes in programmed output voltage are to be made by abrupt changes in programming-resistance, use make-before-break switching.

3-15. To adapt unit for resistance-programming operation, proceed as follows:

a. Set unit circuit breaker to OFF.

b. Remove link between terminals 6 and 7 (Figure 3-3), and connect in programming resistor. Use shielded or twisted wire for interconnecting leads.

c. Rotate COARSE and FINE VOLTAGE ADJUST controls fully counterclockwise.

Note

The VOLTAGE ADJUST potentiometers are in series with the programming resistor. Rotation of either control will alter the programmed voltage.

d. Rotate CUR. ADJUST AMPS. control to desired limiting value, and then connect load to output terminals.

Note

To avoid possible loss of regulation when operating near the limit point, set the CUR. ADJUST AMPS. control at least 3% above the desired maximum operating current.

e. Set unit circuit breaker to ON. Unit supplies programmed voltage to load.

CAUTION

If programming operation is to be discontinued, open unit circuit breaker, remove programming resistor and insert link between terminals 6 and 7.

3-16. PRECISION CALIBRATION. If the ohms/volt coefficient is not sufficiently precise (±10%) for a particular operation, the voltage-mode-amplifier reference circuit may be recalibrated to give an exact coefficient.

a. Rotate COARSE and FINE VOLTAGE ADJUST controls fully counterclockwise.

b. Remove link between terminals 6 and 7 (VOLT PROG) on rear terminal board.

c. Connect a precision* 3.2k ohm (Models 40-20 A and 80-10A) or a 3k ohm (Models 60-13A, 150-5A or 300-2.5 A) resistor between terminals 6 and 7.

d. Connect a precision** voltmeter across output terminals. Select a voltmeter range compatible with rated output.

e. Set unit circuit breaker to ON. Allow at least a 30 minute warm-up period.

f. Adjust potentiometer R44, located near terminal board, for approximately rated output.

g. Short circuit precision resistor.

h. Adjust potentiometer R47, located near terminal board, for a 0 ± .1 volt output (reset voltmeter range).

i. Remove short circuit, reset voltmeter range and adjust R44 for E_o rated ± 0.3%.

j. Disconnect precision voltmeter.

Note

Unit is now calibrated precisely to listed (Table 1-1) ohms/volt coefficient ± (0.3% + tolerances of precision resistor and voltmeter, and regulation of unit). Linearity of programming is ±0.5%.

k. Remove precision calibrating resistor and insert programming resistor. Refer to para 3-14.

3-17. SIGNAL PROGRAMMING. A fixed or variable voltage signal may be impressed on the voltage-mode-amplifier reference circuit to provide a fixed or variable voltage output. The volt/volt coefficient of the 800-Watt-Series models are listed in Table 1-1. When selecting a signal source, assure that it is capable of absorbing at least 3 mA and that it is floating (ungrounded). The procedure for hooking up the signal mode is identical to that for resistance programming (Para 3-15) with this exception: instead of connecting the programming resistor, connect the signal source across terminals 6 and 7.

3-18. ALTERNATE PROGRAMMING METHOD. As mentioned previously, rotation of either output control will affect the output voltage, regardless of whether resistance or signal programming is used. If this is an undesirable feature, bypass the VOLTAGE ADJUST controls by first removing the link between terminals 6 and 7 and then connecting a programming device in series with a resistance equal in value to the setting of potentiometer R47 between terminal 6 on terminal board and terminal stud A, located on component board.

3-19. CURRENT-MODE OPERATION.

3-20. In current-mode operation, the current output is regulated at the value determined by the setting of the CUR. ADJUST AMPS. control. The output voltage, on the other hand, varies as a function of load. To operate unit in the current mode proceed as follows:

a. Rotate FINE and COARSE VOLTAGE ADJUST and CUR. ADJUST AMPS. controls fully counterclockwise.

* Precision of this resistor depends on accuracy of programming sensitivity desired

** ± 0.01% Accuracy.

b. Set unit circuit breaker to ON.

c. Rotate COARSE VOLTAGE ADJUST until unit voltmeter indicates 3% Eo max. higher than the load requires.

Note

The additional 3% E_0 max. is required to avoid unnecessary loss of regulation. See Fig. 1-2.

d. Set unit circuit breaker to OFF.

e. Connect load to terminals 9 and 10. Observe polarity.

f. Turn CUR. ADJUST AMPS. control to desired current-regulation setting.

g. Set unit circuit breaker to ON. POWER and CURRENT MODE lights glow and unit supplies constant, regulated current to load.

Note

If voltage increases above limit set in step "c", unit automatically crosses over to voltage-mode operation.

3-21. RESISTANCE PROGRAMMING. Any DCRA model may be programmed externally to provide a fixed, or variable, predetermined output current. This is done by inserting a resistor, fixed or variable, into the current-mode-amplifier reference circuit.

3-22. The ohms/ampere coefficient for each Model is listed in Table 1-1. Programming current is about 3 mA. Select a resistor with a low temperature coefficient (± 30 ppm) and a wattage rating of at least 10 times that calculated.

3-23. To adapt unit to the current-mode resistance-programming configuration, refer to Fig. 3-4 and proceed as follows:

a. With unit circuit breaker OFF, remove link between terminals 4 and 5, and then insert programming resistor. Use twisted wires for resistor leads.

b. Rotate CUR. ADJUST AMPS. and FINE and COARSE VOLTAGE ADJUST controls fully counterclockwise.

c. Set unit circuit breaker to ON.

d. Rotate COARSE VOLTAGE ADJUST until unit voltmeter indicates output voltage 3% Eo max. above desired voltage-limit value.

Note

The additional 3% Eo max. is required to avoid unnecessary loss of regulation. See Fig. 1-2.

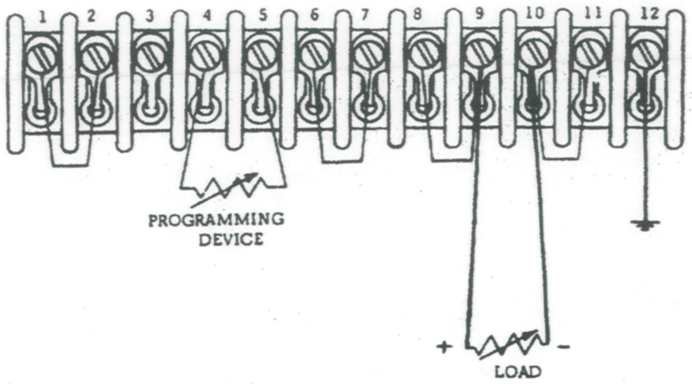


Figure 3-4. Current Mode Prog. Hookup

e. Set circuit breaker to OFF, and connect load leads to output terminals, observing polarity.

f. Set unit circuit breaker to ON. POWER and CURRENT MODE lamps glow.

CAUTION

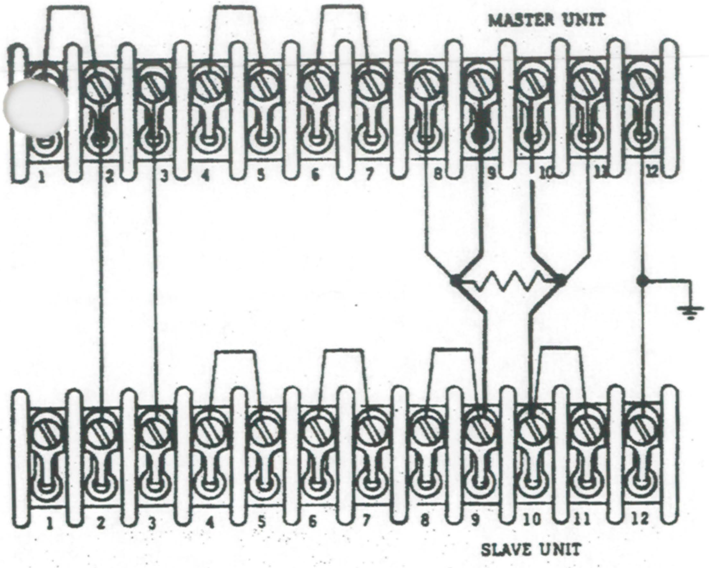
If resistance programming is to be discontinued, remove programming device, and reinsert link between terminals 4 and 5.

3-24. SIGNAL PROGRAMMING. The procedure for adapting a DCRA unit to current-mode signal programming is identical to that for current-mode resistance programming, with this exception: instead of the programming resistor, connect the signal source across terminals 4 and 5. Use twisted wires for the interconnecting leads. Select a floating (ungrounded) signal source capable of absorbing approximately 5 mA. For a full-range variation in unit output current, signal must have a 0-0.6 V range.

3-25. ALTERNATE PROGRAMMING METHODS. For each of the two current-mode programming operations previously described there is an alternate method which bypasses the CUR. ADJUST AMPS. control. For resistance programming, remove the link between terminals 4 and 5, and then connect the programming resistor between terminal 4 and terminal stud D on component board. In signal programming, connect signal source across studs D and F on component board. Signal-range required will be slightly greater than that stipulated in 3-24.

3-26. PARALLEL OPERATION.

3-27. DCRA single-phase units may be paralleled using either of two methods. One method uses a "master-slave" approach, and the other involves direct paralleling. Each method has its advantages



Note: Connect unit inputs to same source.

Figure 3-5. Master - Slave Parallel Hookup (with Remote Sensing)

and also its drawbacks. In "master-slave" operation, output-voltage-regulation specifications are maintained. However, only four units may be paralleled, and output current of each unit must be derated to 90%. With the direct method, there is no limit to the number of units which may be paralleled, and no current derating is required. However, output-voltage regulation does deteriorate.

3-28. MASTER-SLAVE PARALLELING. Refer to Fig. 3-5. Instructions for hooking up two units in parallel follow; additional "slaves" may be added by extending this procedure.

a. Connect input power cables to same input source.

b. With no load applied, set "master" unit circuit breaker to ON, and adjust voltage to desired system output, plus total load lead drop if use of remote sensing is desired. Switch circuit breaker to OFF.

c. Recalibrate "master" unit current-mode circuit per para 3-12, if remote sensing is desired.

d. Connect load leads from both units to load. If possible, use loads leads of approximately equal length. Observe polarity.

e. Disconnect link between terminals 1 and 2 on "slave" unit, and interconnect terminals 2 of "master" and "slave".

f. Run a lead between terminal 3 of "master" and "slave" units.

g. For remote sensing, remove links between terminals 8 and 9, and 10 and 11 on "master" unit, and run sensing leads between terminals 8 and 10 and the load. Observe polarity. Use twisted wire or shielded cable.

h. Set "master" unit's circuit breaker ON first and then "slave" unit's.

Note

In shutting down system, set "slave" circuit breaker OFF first, then turn off "master" unit.

3-29. DIRECT PARALLELING. The following steps give the procedure for direct paralleling two units. The procedure need only be extended to parallel additional units.

a. If remote sensing is to be used, recalibrate current-mode circuit of each unit per para 3-12.

b. At no load, adjust individual output voltages to desired system output. Attempt to match individual unit outputs with FINE VOLTAGE ADJUST controls.

c. Set unit circuit breakers to OFF, and run load leads from units to load. Observe polarity (see Figure 3-6).

d. If remote sensing is to be used, connect sensing leads from units to load. See Fig. 3-6. Observe polarity. Use twisted wire or shielded cable for leads.

e. Set CUR. ADJUST AMPS. control on each unit to one-half of the total limiting current, e.g., if desired to limit load current to 2 A, set each control to 1 A.

f. Set both unit circuit breakers to ON. POWER indicators glow. Output voltages will not be identically matched. The unit which is supplying

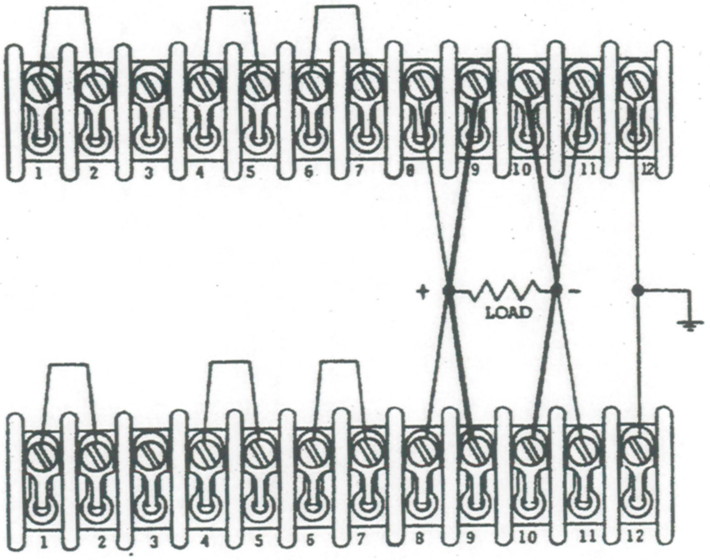


Figure 3-6. Direct Parallel Hookup (with Remote Sensing)

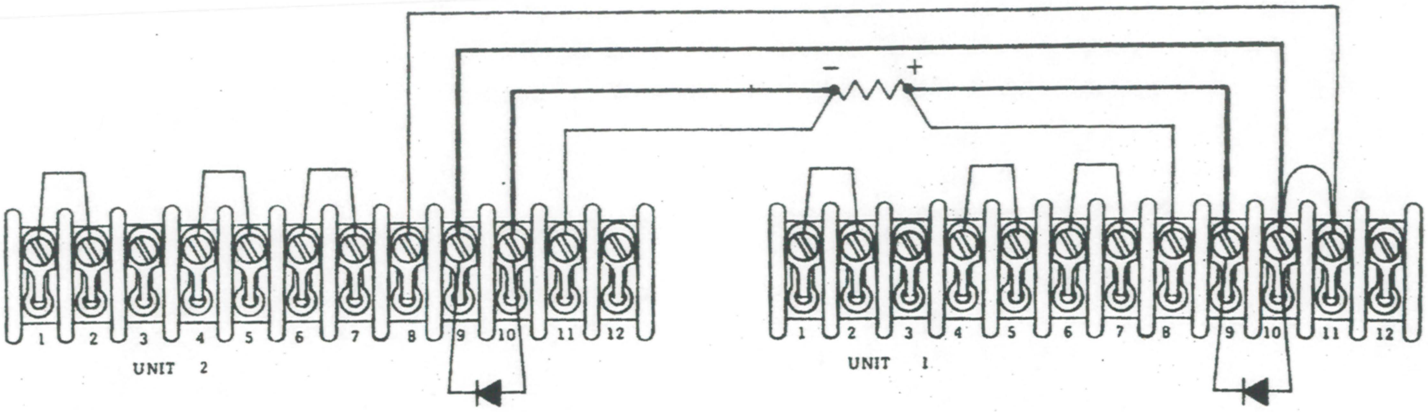


Figure 3-7. Series Operation

the highest voltage will supply the load. If the load requirements exceed the setting on CUR. ADJUST AMPS. control, this unit will automatically crossover to current-mode operation, and its output voltage will drop. The second unit will then assume that portion of the load rejected by the first. Any further increases in load will be supplied by the second unit up to its current-limiting setting. Regulation, therefore, will be the sum of the regulations of the two units (or whatever number of units are being paralleled), plus the difference in the voltage settings.

3-30. SERIES OPERATION

3-31. Series operation may be used for applications requiring output voltages higher than a single unit can provide. The number of units which may be series connected is listed by Model in Table 1-1. Regulation is the sum of the regulations of all units. To hook up a series system proceed as follows:

a. Recalibrate the current-mode circuit (para 3-12) of the unit at which the negative load lead will terminate (in Figure 3-7, this is unit 2).

b. Set individual unit circuit breakers to ON and adjust output voltages until their sum is the desired system output plus the load-lead voltage drops. Set breakers to OFF.

c. Select a setting for CUR. ADJUST AMPS. control on each unit, noting that system output current is limited to the lowest value set on either current control.

d. Remove links between terminals 8 and 9, and 10 and 11 on both units. Hook up load leads first and then sensing leads. Use twisted wires or shielded cable for sensing leads where possible. Connect protective rectifiers across output as shown in Figure 3-7. Refer to para 3-32 for rectifier recommendations.

e. Set each unit circuit breaker to ON. Output of each unit reamins independently adjustable.

3-32. RECTIFIER RECOMMENDATIONS.

3-33. If during series operation a unit fails or is shut off, reverse voltage will be applied across the failed unit's output terminals, damaging the output capacitor and possibly the unit ammeter and bleeder resistors. To protect these components, connect a rectifier across each set of output capacitors used in the system. Protective rectifiers recommended for series operation are listed in Table 3-2. The heat sinks have been selected on the assumption that a forward- and reverse-polarity rectifier will be mounted on each heat sink. Use a mica washer between rectifier and heat sink for DCR Models 150-5A and 80-10A.

DCR MODEL	MFR.	MFR. (1) PART NO.	SORENSEN PART NUMBER	HEATSINK DIM. (Flat, Al. plate) inches
300-2.5A	Solitron	3A 400	26-1026-7	None Required
150-5A (2)	Motorola	MR 1122	26-1046-4	1-3/4 x 1-3/4 x 1/32
		MR 1122R	26-104-14	
80-10A (2)	Motorola	MR 1121	26-1046-2	3 x 3 x 1/32
		MR 1121R	26-1046-12	
60-13A (2)	Motorola	MR 1121	26-1046-2	2-3/4 x 2-3/4 x 1/8
		MR 1121R	26-1046-12	
40-20A (3)	G. E.	IN 1183	26-829	3-1/2 x 3-1/2 x 1/8
	G. E.	IN 1183R		

(1) Reverse-polarity rectifiers are designated by the letter R following the manufacturer's part number.
(2) Stud diameter is 0.190 in. (#10), width across the flats is 7/16 in., and mounting torque is 12 to 15 lb.-in.
(3) Stud diameter is 1/4 in., width across flats is 11/16 in., and mounting torque is 20 to 30 lb.-in.

Table 3-2. Recommended Rectifiers, Series Operation.

SECTION IV
PRINCIPLES OF OPERATION

4-1. INTRODUCTION.

4-2. This section provides a basic discussion of unit operating principles which, when used in conjunction with the troubleshooting procedures given in Section V, will enable the logical and rapid isolation of unit faults.

4-3. To facilitate the treatment of what is a relatively complex subject a brief description of the phase-control principle is given first. This is followed by a general discussion of section functions. Each section is then described in detail.

4-4. PHASE-CONTROL PRINCIPLE.

4-5. To understand phase-control, consider Figure 4-1. The sinusoidal wave represents normal a-c line voltage. If, by some means, conduction of this voltage can be delayed, the average voltage output will be reduced. Control of the delay then results in control of the average voltage. This is phase control and the device used in the DCR to cause the delay is the silicon controlled rectifier (SCR). The delay is expressed in degrees and is known as the firing angle. Figure 4-1 shows firing angles of 60° (shaded area plus cross-hatched area) and 120° (cross-hatched area only).

4 6. BLOCK-DIAGRAM DISCUSSION.

4-7. Refer to Figure 4-2: voltage is applied to the input transformer through the SCR network. Output of the transformer is then rectified, L-C filtered and fed to the output terminals. The voltage-mode section monitors the output voltage and compares an attenuated sample with the regulated votage produced by the reference supply. Comparison error signals are amplified and then transmitted to the mixer. At the mixer, the d-c error signals are combined with the sawtooth-generator output and are then fed to the multivibrator. The multivibrator develops a rectangular wave output, with the duration of each pulse directly related to the d-c level of the input signal. Next, the signal is inverted and applied to a transistor switch, where it determines the transistor's on-off state. In the "on" state, the switch prevents operation of the relaxation oscillator. With the switch in the "off" state, the oscillator functions to pulse the SCR's into conduction. The firing angle then is dependent upon the on-off condition of the switch, and this, in turn, is dependent upon the d-c signal received from the voltage-mode section. Figure 4-3 depicts an idealization of how the d-c signal level alters firing angle. For simplification, the inverter and switch section have been omitted. Returning to Figure 4-2, the synchronizing section functions to maintain an in-phase relationship between the input voltage and the firing pulses.

4-8. REFERENCE SUPPLY.

4-9. The precisely regulated voltage required for operation of the various control sections is produced by a reference supply consisting basically of a zener diode (CR36), two differential amplifiers (Q23, Q24 and Q21, Q22), passing stage (Q19) and an unregulated supply (transformer (T2), center-tapped, full-wave bridge rectifier (CR34, CR35), and filter capacitor (C20)).

4-10. Supply output is sensed across potentiometer (R68), which, along with resistor (R67) and zener diode (CR36), forms a comparison bridge. Error signals developed are differentially amplified first by Q23, Q24 and then by Q21, Q22. The amplified signals are applied to the base of Q19, changing the absorbed voltage across the stage and regulating the output to a precise 20 volts. As an illustration of circuit operation, assume that the supply's output voltage begins to rise. The base of Q23 will then become

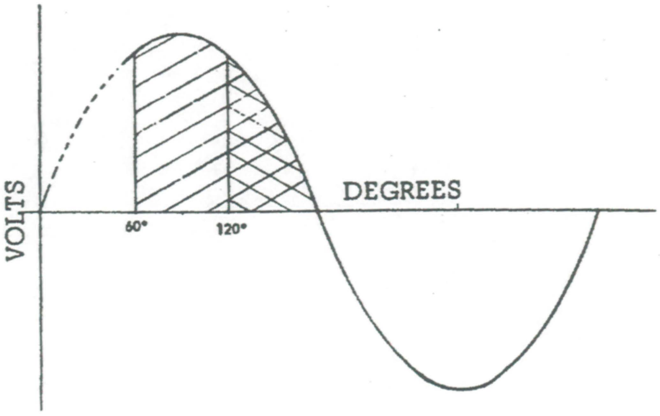


Figure 4-1. Phase Control Firing Angles

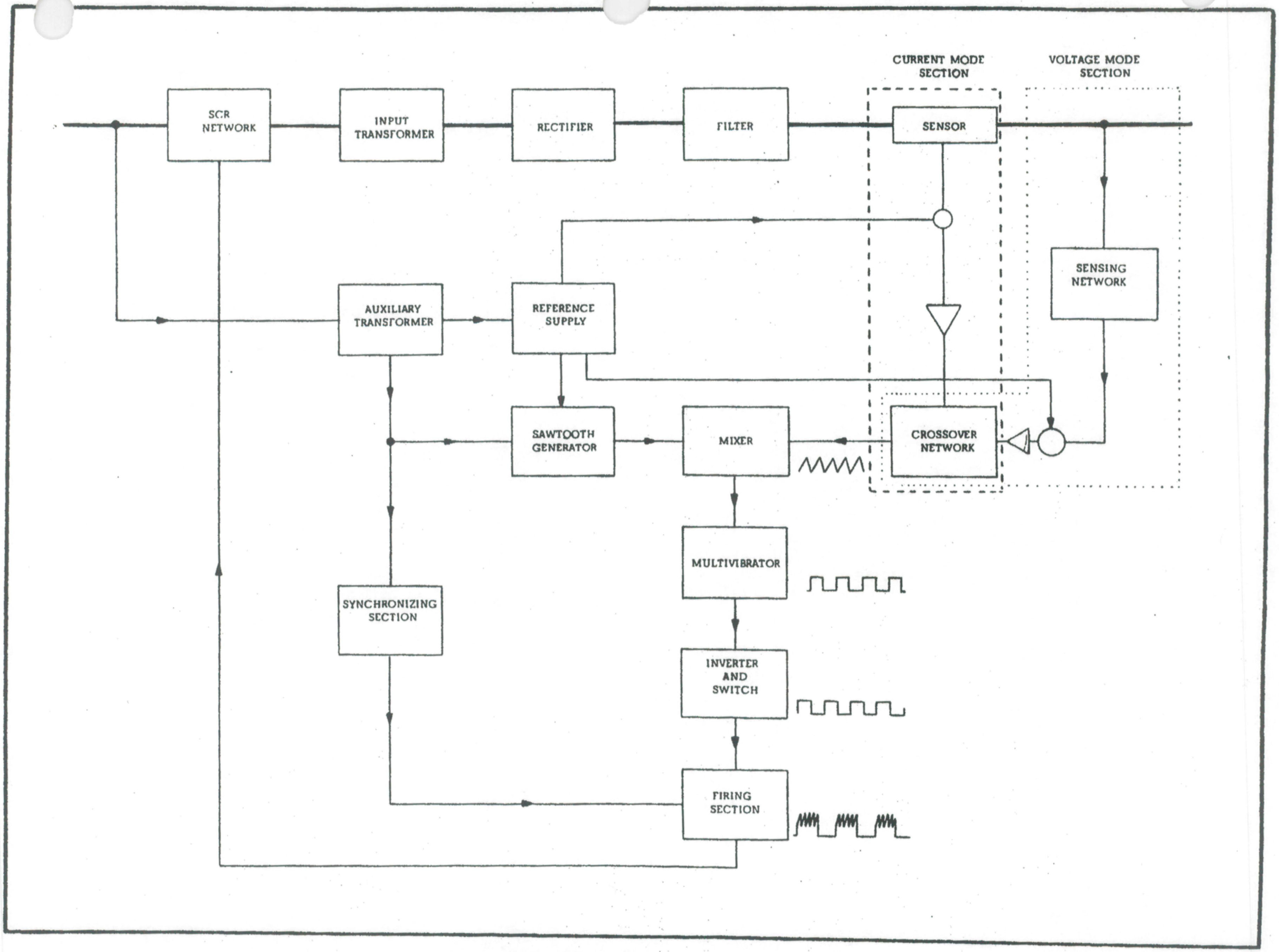


Figure 4-2 . Block Diagram

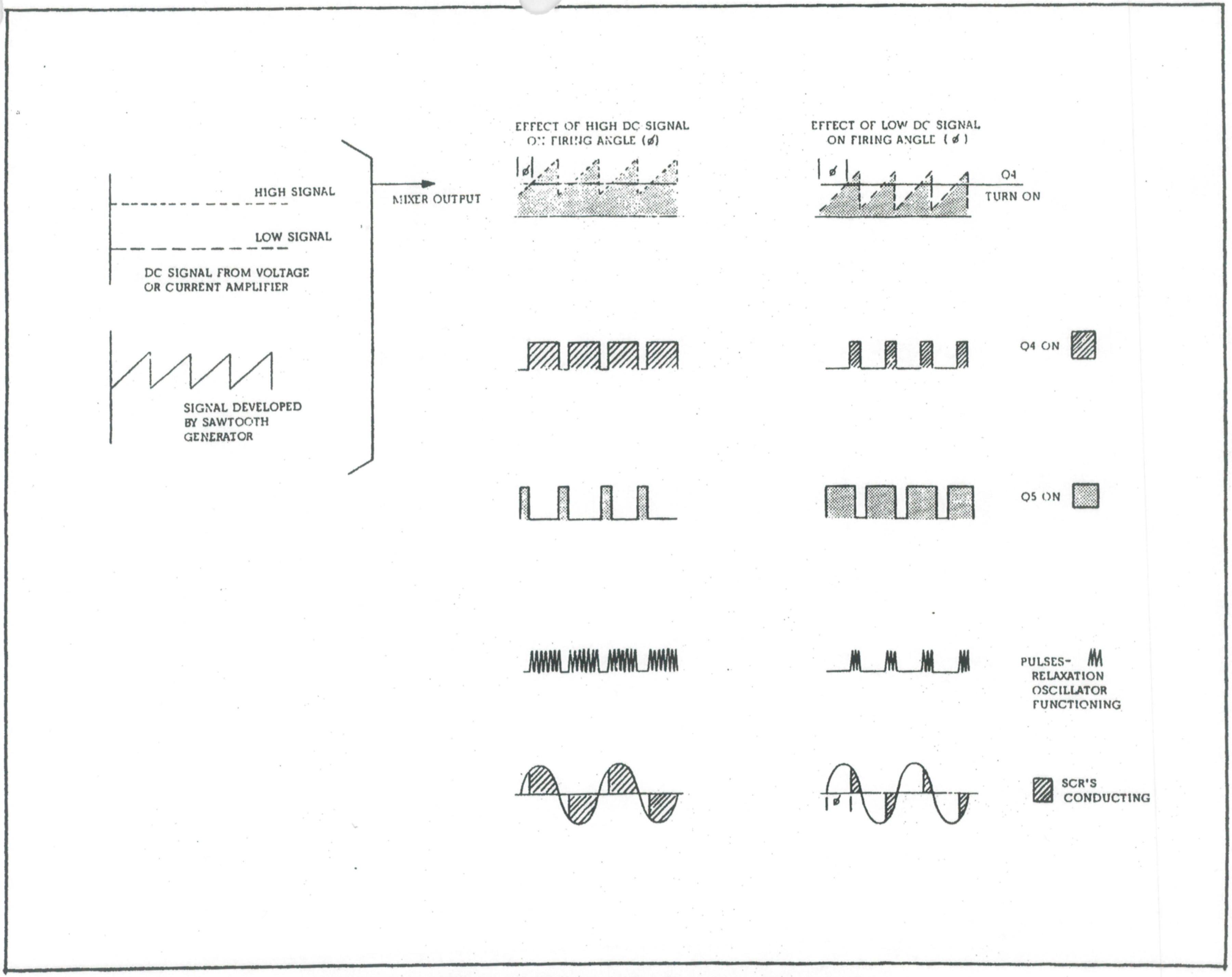


Figure 4-3. Effects of High and Low Signals on Firing Angle

more positive with respect to the base of Q24, Q23 will conduct more current and R64 develops a higher voltage. (Note that the sum of the operating currents of Q23 and Q24 is fixed by the constant voltage developed by CR36.) With an increase in voltage across R64, the base of Q22 becomes more negative with respect to the base of Q21, and Q21 conducts more current. Q21's operating current and the drive current to Q19 are supplied by constant-current generator (R79, CR38), and therefore, an increase in current through Q21 reduces the drive on Q19. With a reduction in drive current, Q19's impedance increases (as does the absorbed voltage) and the supply's output is regulated to a precise 20 volts.

4-11. VOLTAGE-MODE SECTION.

4-12. The voltage-mode amplifier compares a portion of the unit output voltage against a manually variable reference, differentially amplifies error signals developed and transmits the amplified signals to the mixer section. Basic functional components include beta network (R56 R57), differential amplifier (Q15, Q16), reference string (R41, R44 through R47), and constant current generators (Q12, Q14 and Q17).

4-13. The circuit functions as follows: the output voltage is divided across beta network (R56, R57), with a voltage sample appearing at the base of Q16. This voltage is compared with the reference voltage at the base of Q15. Resulting error signals, differentially amplified, are sent to the mixer section. To illustrate circuit operation, assume that the output voltage begins to rise. The base of Q16 becomes more positive with respect to the base of Q15. As a result, Q16 conducts more current. (Note that the sum of Q15's and Q16's operating currents is held constant by current generator Q17). Q15 then conducts less, and the voltage across R49, the amplifier-output resistor, drops. The reduced signal is sent to the mixer, and results in an increase in firing angle and, therefore, a reduced output.

4-14. The constant-current generators, although operating in basically the same manner, have separate functions. Q17 maintains the sum of the operating currents through Q15 and Q16 constant. This sum would otherwise be dependent upon the manually variable voltage developed across R45, R46, and B47. Generator Q12 provides operating current to Q15 allowing R49 to have a relatively large value and therefore increasing amplifier gain. In the reference string (R44, R41, R45, R46 and R47), generator Q14 produces a constant current to insure linearity of the reference circuit. The basic operation of all generators is the same: a fixed voltage is applied across a resistor and the base-emitter junction of a transistor. With the transistor conducting, the resistor produces a constant current. As an example, examine Q12's circuitry. The 20-volt reference supply is across divider (R38, R40). Therefore, a constant voltage is developed across R38. This voltage also appears across Q12's base-emitter and resistor R39, and a constant current develops as explained above.

4-15. CURRENT-MODE SECTION.

4-16. The current-mode section senses output current, and if the current increases to the CUR. ADJUST AMPS. (R31) setting, effects the crossover to current-regulating operation. Main components include sensing resistor (R4) and transistors (Q11 and Q13). Lamp (DS3) and transistor (Q25) form the current-mode indicating circuit.

4-17. To illustrate section operation, assume that the output current approaches the current-limit setting. The voltage developed across resistor R4 increases, and the base of Q11 becomes more positive with respect to its emitter. Q11 will therefore conduct less current, and the voltage drop across R34 will decrease. The base of Q13 will then become more negative with respect to its emitter and Q13 will conduct. Q13's output is directed both to the base of Q25 and to the emitter of constant-current generator Q17 through CR30. Q25 is driven into conduction, and the indicator light glows. With the dropping output voltage, Q16 cuts off and Q15 goes into saturation. The current from Q13 becomes part of the constant-current generator's output. As a result, the current through Q15 and R49 decreases and the voltage developed across R49 drops. This voltage is the signal to the mixer stage, and, as it decreases, the SCR firing angle increases, limiting the output current and resulting in current regulation at R31's setting.

4-18. SAWTOOTH-GENERATOR SECTION.

4-19. The sawtooth waveform, a component of the multivibrator input signal, is developed by a circuit comprised of voltage divider (R9, R10), switch (Q1), R-C network (R13, C5), emitter follower (Q2), load resistor (R14), and d-c blocking capacitor (C6). Diode (CR14) prevents the buildup of reverse base-emitter voltage.

4-20. The section functions as follows: 20 volts from the reference supply and -35 volts (pulsating DC), provided by an unregulated supply (transformer T2, diodes CR12 and CR13), are divided across R9 and R10 to provide a pulse signal to the base of switch Q1. Q1 is then turned off and on at approximately fixed intervals, allowing capacitor C5 to charge and discharge. During the charging period, Q2 is biased on by a signal developed by the R-C net-

work ramp. Q2's operating current, and therefore the voltage across R14, also track the R-C ramp. When Q1 is biased on, capacitor C5 discharges and Q2 is cut off, dropping the voltage across R14 to zero and forming the sawtooth wave.

4-21. MIXER SECTION.

4-22. The mixer section amplifies a d-c signal, derived from either the voltage- or current-mode amplifier, and combines it with the input wave from the sawtooth generator. Mixer components include transistor Q3 and resistors R15 and R16. Capacitor C7 provides stabilization, and capacitor C8 attenuates circuit-noise sensitivity.

4-23. The section functions as follows: a signal, controlled by either the voltage- or current-mode amplifier, is applied to the base of Q3. Q3's operating current changes, and results in a change in the d-c voltage developed across R16. This voltage is combined, or "mixed", with the sawtooth input and applied to the multivibrator section.

4-24. MULTIVIBRATOR SECTION.

4-25. A bistable multivibrator (Schmitt Trigger) using a mixed sawtooth and d-c input, produces rectangular pulses of controlled duration to trigger the firing circuit. Section components include transistors Q4 and Q5, and resistor strings R17, R19, R21 and R22, R23, R20, R18.

4-26. To illustrate circuit operation, assume Q4 to be off. Q5 will then be conducting, and the voltage across R22 will be at the maximum. As the input signal voltage follows the sawtooth ramp, it becomes greater than the voltage developed across R18. Q4 then begins to conduct, and as a result, the potential at the base of Q5 drops rapidly forcing Q5 into cut off. Subsequently, the voltage across R22 collapses. Q4 continues to conduct until the sawtooth peaks, and then cuts off with the drop in input signal. Simultaneously, Q5 quickly saturates, rapidly building up the voltage across R22. The signal developed across R22 then is a rectangular pulse, whose duration is inversely dependent on the magnitude of the input signal. This signal, as mentioned before, is mixed sawtooth and d-c. The rise and fall times of the sawtooth are very nearly constant; therefore, pluse duration is determined only by the amplified d-c signal from the voltage- or current-mode amplifiers.

4-27. INVERTER AND SWITCH SECTION.

4-28. Transistors (Q6, Q7) and resistors (R24, R25) form an inverter and switching circuit. Multivibrator output, developed across R22, is inverted by Q6 and applied to the base of Q7. Q7's duration in the on state is directly related to the duration of the input pulse. This is an important point in understanding how the firing section is controlled.

4-29. FIRING SECTION.

4-30. The firing section consists of a relaxation oscillator and transformers T3 and T4. Oscillator components include resistor R26, capacitor C10, unijunction transistor Q8 and resistor R27. The circuit functions as follows: capacitor C10 charges through R26 until the potential at the emitter of Q8 surpasses the breakover voltage. Q8 then conducts, C10 discharges through it and either transformer T3 or T4 is pulsed (para 4-31). A discharging C10 drops the emitter voltage, and Q8 cuts off. The cycle repeats at a rate determined by the time constant of R-C network (R26, C10). It should be noted that if switch Q7 (refer to para 4-27) is on, C10 will not charge and the oscillator will not function. Switch Q7's state then determines SCR firing angles.

4-31. SYNCHRONIZING SECTION.

4-32. Two silicon controlled rectifiers, connected in parallel, phase control the input to transformer T1. When pulsed each of these devices, due to inherent forward-reverse bias characteristics, operates during a particular half-cycle of the a-c input. Under normal conditions, there is no need to synchronize the firing pulses with the operable SCR since pulsing of the reverse-biased SCR will not cause conduction. However, under certain load-change conditions, transformer T1 leakage inductance may cause a voltage to appear across each SCR. If this voltage is of sufficient magnitude and direction, the improper SCR will become forward biased resulting in conduction for more than 180°. Consequently, transformer T1 saturates and the unit circuit breaker trips. To prevent this, the synchronizing section functions to insure gating of the proper SCR only. The section is comprised of transformer T2, resistor R11, R12, R28 and R29, diodes CR18 through CR21 and transistors Q9 and Q10.

4-33. A description of circuit operation follows: the output from transformer T2 is clipped by diodes CR18, CR19 and CR20, CR21 to provide periodic flat rectangular pulses, in phase with the input voltage.

These pulses are applied to the bases of Q9 and Q10, alternately biasing one transistor on and cutting the other off. The biasing then is synchronized with the input so that the transistor which is on permits pulsing of the proper SCR.

4-34. POWER SECTION.

4-35. In the power section, AC is applied to T1's primary winding through an input filter (L2) and SCR switches (CR7, CR8). Secondary output is rectified by a full-wave bridge (CR1-CR4) and L-C filtered by choke L1 and capacitor C1 before being delivered to the output terminals. (Note that the DCR 300-2.5A utilizes two full-wave bridge rectifiers at T1's secondary.) Capacitor C28 acts as a high-pass filter to minimize the effect, on the input waveform, of CR7 and CR8 switching. Diodes CR6 and CR9 function as blocking diodes, preventing the buildup of excessive reverse bias on the CR7-CR8 gates and possible random firing signal resulting from spurious noise.

4-36. THERMAL OVERLOAD SECTION

4-37. The thermal overload section operates at high unit temperatures to drop the output to zero. Consisting of thermostat S1, indicating lamp DS2 and resistor R73, the section derives its power from an unregulated supply (CR34, CR35). When unit internal temperature rises to about 195 °F, thermostat S1 closes and the voltage introduced across resistor R50 develops sufficient current to prevent the build up of a signal across resistor R49. As a result, no signal is transmitted to the mixer section, Q4 in the multivibrator remains off, no pulses are developed by the firing sections and thus the SCR's are in a blocking condition, preventing the development of current or voltage output. Resistor R73 allows the section to function in the event of lamp DS2 failure.

SECTION V
MAINTENANCE

5-1. GENERAL.

5-2. This section provides troubleshooting data, periodic servicing, and calibration and performance-testing procedures. The troubleshooting data should be used in conjunction with both the schematic diagram (Figure 5-4) which gives voltage check points, and Section IV, which outlines the principles of operation. In addition, Figures 5-1 and 5-2 physically locate the parts referred to in the text. Any questions pertaining to repair should be directed to the nearest Sorensen representative (a list is included with the unit) or to the Service Dept., Raytheon Co., Sorensen Operation, Richards Avenue, Norwalk, Connecticut 06856. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, authorization from the Sorensen Service Dept. must be obtained first. Raytheon Company will not assume responsibility for units returned without prior authorization.

5-3. PERIODIC SERVICING.

5-4. The 800-Watt-Series units require periodic lubrication of the cooling fan. The intervals at which the fan is to be oiled are a function of both the unit's duty cycle and the ambient temperature. If the unit is operated continuously in high ambients, the fan should be lubricated every 6 months. If, on the other hand, the unit is operated intermittently at room temperatures (20 to 25°C) or below, lubrication need only take place at 12-month periods. For operating conditions between the two duty and temperature extremes, select an interval between 6 and 12 months. The lubricant recommended by the Rotron Manufacturing Company, Woodstock, N.Y. is supplied in kit form and may be purchased under Rotron part number 19263.

5-5. It is recommended that whenever a unit is removed from the line, it be cleaned. Use naptha, or an equivalent solvent, on painted surfaces. Wash front panel with a weak solution of soap and warm water. Use compressed air at a pressure of 5 psi to blow dust from in and around components.

5-6. TROUBLESHOOTING.

5-7. Table 5-1 provides a list of malfunction symptoms along with a tabulation of the possible cause or causes for each symptom. Note that the failure of a single component may result in a "chain-reaction" effect. For example, if diode CR34 shorts, diode CR35 may overload and then short, causing the subsequent failure of transformer T2. As additional aids to troubleshooting, voltage checkpoints have been designated on the schematic diagram, Figure 5-4, and X-Y plots, provided in Figure 5-3, show normal waveforms developed across a number of selected components. When a component failure has resulted in high output voltage (meter pointer pegs), reduce danger to maintenance personnel by removing unijunction transistor Q8. This will, in effect, disable the firing circuit and drop the output to zero. (Do not neglect checking Q8. A base-to-base Q8 short will cause high output.)

5-8. CALIBRATION.

5-9. Following repair, the unit should be recalibrated to insure that replacement components have not appreciably altered performance characteristics. When calibrating, follow sequence of the following paragraphs.

5-10. REFERENCE POWER SUPPLY. To calibrate the reference power supply, proceed as follows:

a. Remove unijunction transistor Q8 from socket. Apply nominal input power, and set unit circuit breaker to ON.

b. Connect a precision d-c voltmeter (0-30 Vdc) across capacitor C21. Meter should indicate 20 ± 0.1 volts. Adjust potentiometer R68 to obtain specified voltage.

c. If desired, check reference power supply regulation by varying input voltage from 104 to 126 Vac. Voltmeter should indicate voltage deviation of no more than 4 mV. Disconnect voltmeter.

5-11. VOLTAGE-MODE SECTION. Calibrate the voltage-mode section as follows:

a. Rotate FINE and COARSE VOLTAGE ADJUST controls fully counterclockwise.

SYMPTOM	POSSIBLE CAUSE
I. No Output (Voltage Mode)	a. Check input. b. Thermal overload. c. In reference supply, diode CR37 open (voltage age across capacitor C21 about 7 V) d. In voltage-mode section, 1. transistor Q12 or Q16 shorted 2. transistor Q14, Q15 or Q17 open 3. rectifier CR39 shorted. e. In trigger and firing section, 1. transistor Q3, Q4 or Q8, open 2. transistor Q5, Q6, Q7 or Q8 e-b shorted.
II. Output voltage drops to zero at low settings	In reference supply, shorted diode CR37
III. Circuit breaker tripped	a. In power section 1. diode CR1, CR2, CR3 or CR4 open 2. diode CR1, CR2, CR3 or CR4 shorted* 3. silicon controlled rectifier CR7 or CR8 open. b. In reference supply, check for shorted diode CR34 or CR35 (≠) c. In trigger and firing circuit, 1. diode CR12 or CR13 open. 2. diode CR12 or CR13 shorted. 3. transistor Q9 or Q10 open 4. diode CR16 or CR17 shorted 5. diode CR6 or CR9 open. 6. Q8 b-b shorted d. See Symptom VI
IV. High output voltage (meter pointer pegs)	a. Sensing or programming leads or links open. b. In power section, silicon controlled rectifier CR7 or CR8 shorted. c. In voltage-mode section, 1. transistor Q16 open 2. transistor Q14, Q15, or Q17 shorted 3. diode CR33 shorted, or diode CR39 open d. In trigger and firing section, 1. transistor Q3 or Q4 shorted. 2. transistor Q5, Q6 or Q7 open 3. diode CR15 open.

(*) Check complementary rectifier before returning unit to service.

(≠) Check both rectifiers and transformer T2 before returning unit to service.

Table 5-1. Troubleshooting Data (Sheet 1 of 2).

SYMPTOM	POSSIBLE CAUSE
V. No output (Current Mode)	a. Thermal overload. b. In current-mode section, transistor Q13 shorted or transistor Q11 open. c. In trigger and firing circuit 1. transistor Q3, Q4 or Q8 open. 2. transistor Q5, Q6, Q7 or Q8 e-b shorted
VI. Unit will not operate in current mode (will not current limit)	In current-mode section, 1. Cur. Prog. leads or link open. 2. diode CR23 or CR30 open. 3. transistor Q13 open 4. transistor Q11 or Q25 b-e shorted
VII. Inability to limit at or near I_o max	In current-mode section, 1. diode CR23 or CR30 shorted 2. transistor Q25 open
VIII. Slight increase in output voltage	In reference supply, check voltage across capacitor C21. Should be 20 ± .1 Vdc. Attempt to adjust with potentiometer R68. If voltage is about 12 Vdc, check for 1. open transistor Q24, Q22 or Q19 2. shorted transistor Q21 or Q23 3. shorted diodes CR36 or CR38
IX. Slight decrease in output voltage	Check reference supply output voltage (VIII above). If voltage is about 30 Vdc, check for 1. shorted transistor Q24, Q22, or Q19 2. open transistor Q21 or Q23 3. open diodes CR36 or CR38

Table 5-1. Troubleshooting Data (Sheet 2 of 2).

b. Turn CUR. ADJUST AMPS. control fully clockwise.

c. Set unit circuit breaker to OFF, remove link between terminals 6 and 7, and then connect a milliammeter (0-10 mA) across terminals.

d. Set unit circuit breaker to ON. Ammeter should indicate approximately 3 mA. If necessary, use potentiometer R44 to adjust.

e. Set unit circuit breaker to OFF, disconnect ammeter and reinsert link across terminals 6 and 7. Set breaker to ON.

f. Connect an oscilloscope (vertical -- 5 V/cm, horizontal -- 5 ms/cm) across capacitor C10. Rotate potentiometer R47 counterclockwise, and then clockwise until pulses start to form. Next, rotate slowly counterclockwise. Cease rotation as pulses disappear.

g. Set circuit breaker to OFF; then reinsert unijunction transistor, Q8, into socket.

h. Connect a multirange, sensitive d-c voltmeter across output terminals, select a range compatible with unit output voltage rating, and then set unit circuit breaker to ON.

i. Rotate COARSE VOLTAGE ADJUST control fully clockwise. Test voltmeter should indicate the voltage given in Table 5 - 2 for applicable model. If necessary, adjust using potentiometer R44.

j. Turn COARSE VOLTAGE ADJUST control fully counterclockwise, switch voltmeter range to 100 mV, and adjust potentiometer R47 to obtain a zero ± 50 mV output.

k. Repeat steps i. and j., in sequence, until minimum and maximum voltages are within tolerance specified, and then disconnect voltmeter.

5-12. CURRENT-MODE SECTION. Proceed as follows to calibrate the current-mode section:

a. Set unit circuit breaker to OFF, short

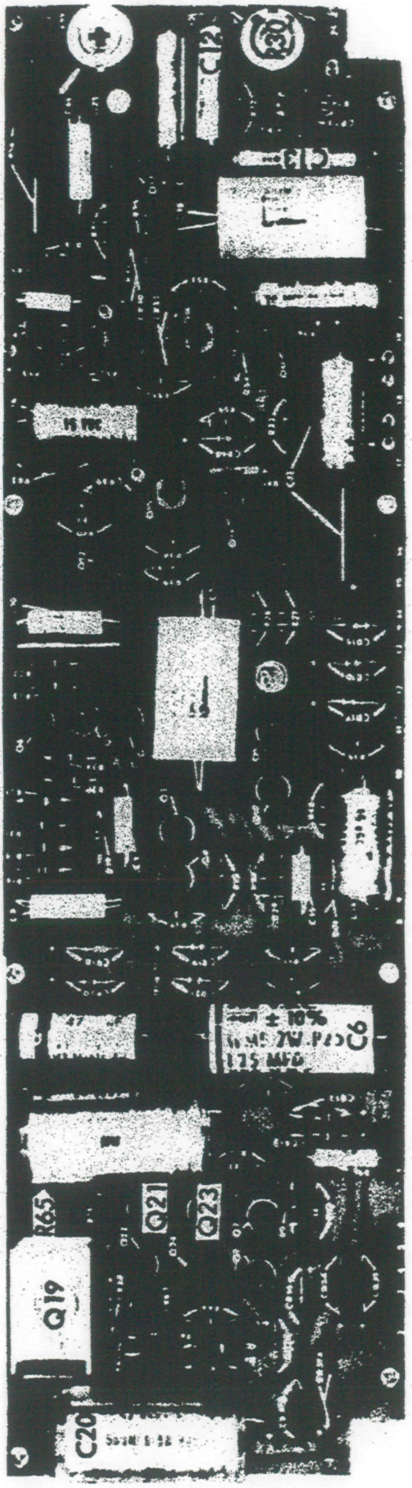


Figure 5-1. Typical Component Board

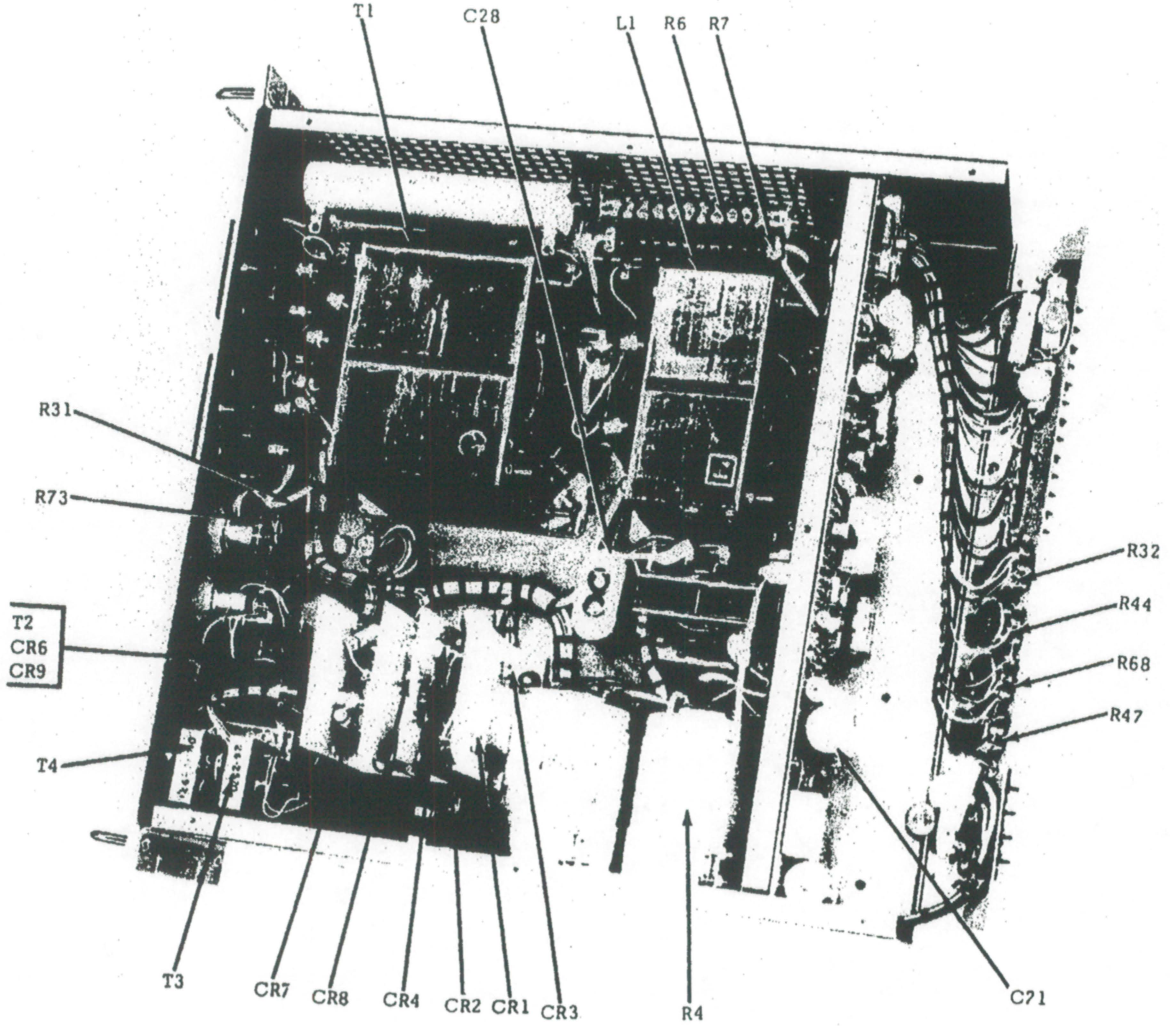
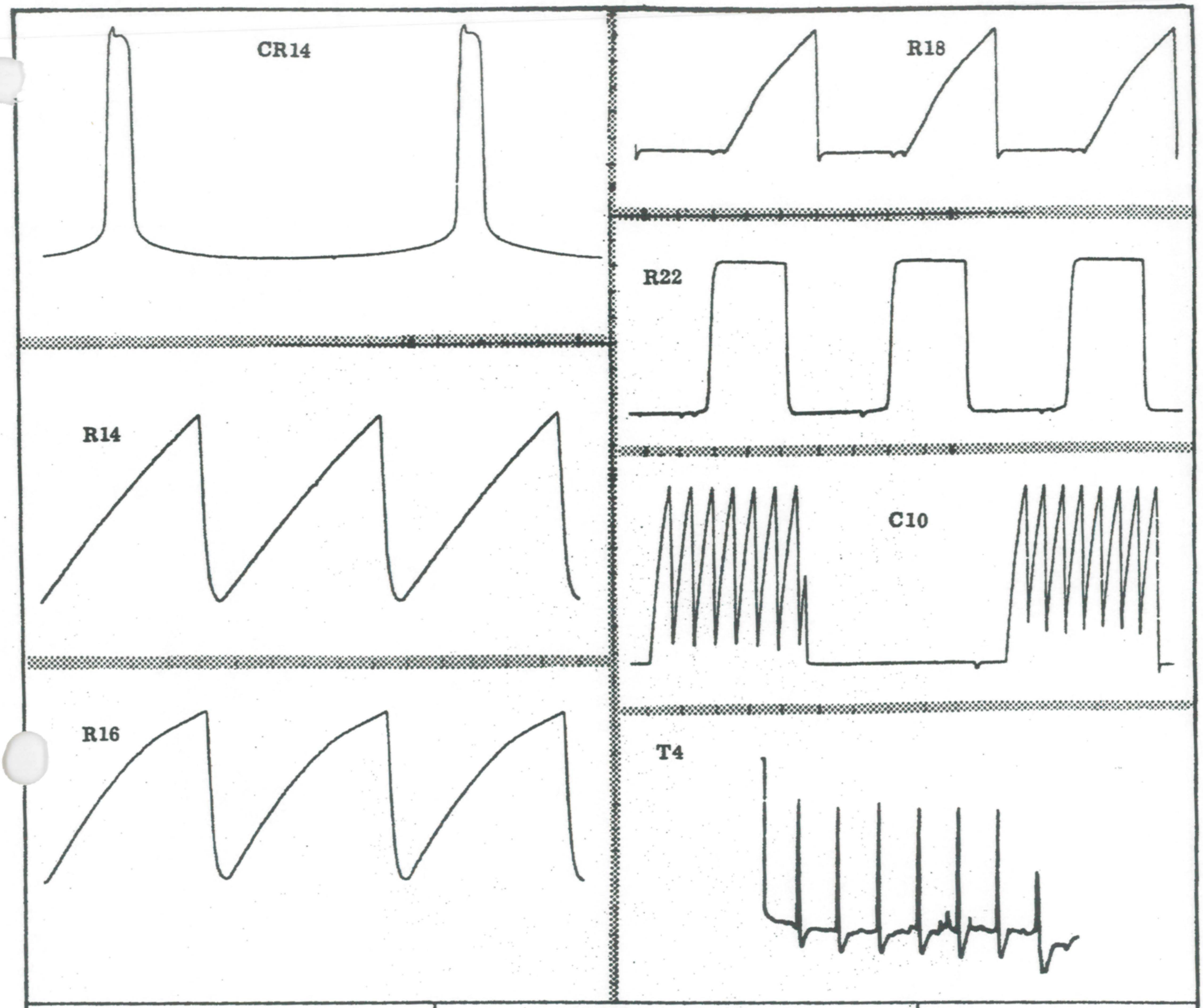


Figure 5-2. Typical Partial Disassembly
Model DCR 40-20A (Shown)



COMPONENT	OSCILLOSCOPE SETTINGS Vertical (V/CM)	Horizontal (MS/CM)	PEAK - TO - PEAK VOLT (Approx.)
CR14	0.5	2	1.5
R14	2	5	3.7
R16	2	5	3.4
R18	1	5	1.8
R22	0.5	5	0.75
C10	5	2	12
T4, TERMS 3 and 4	1	0.4	2.4

Figure 5-3. Selected Signal Traces

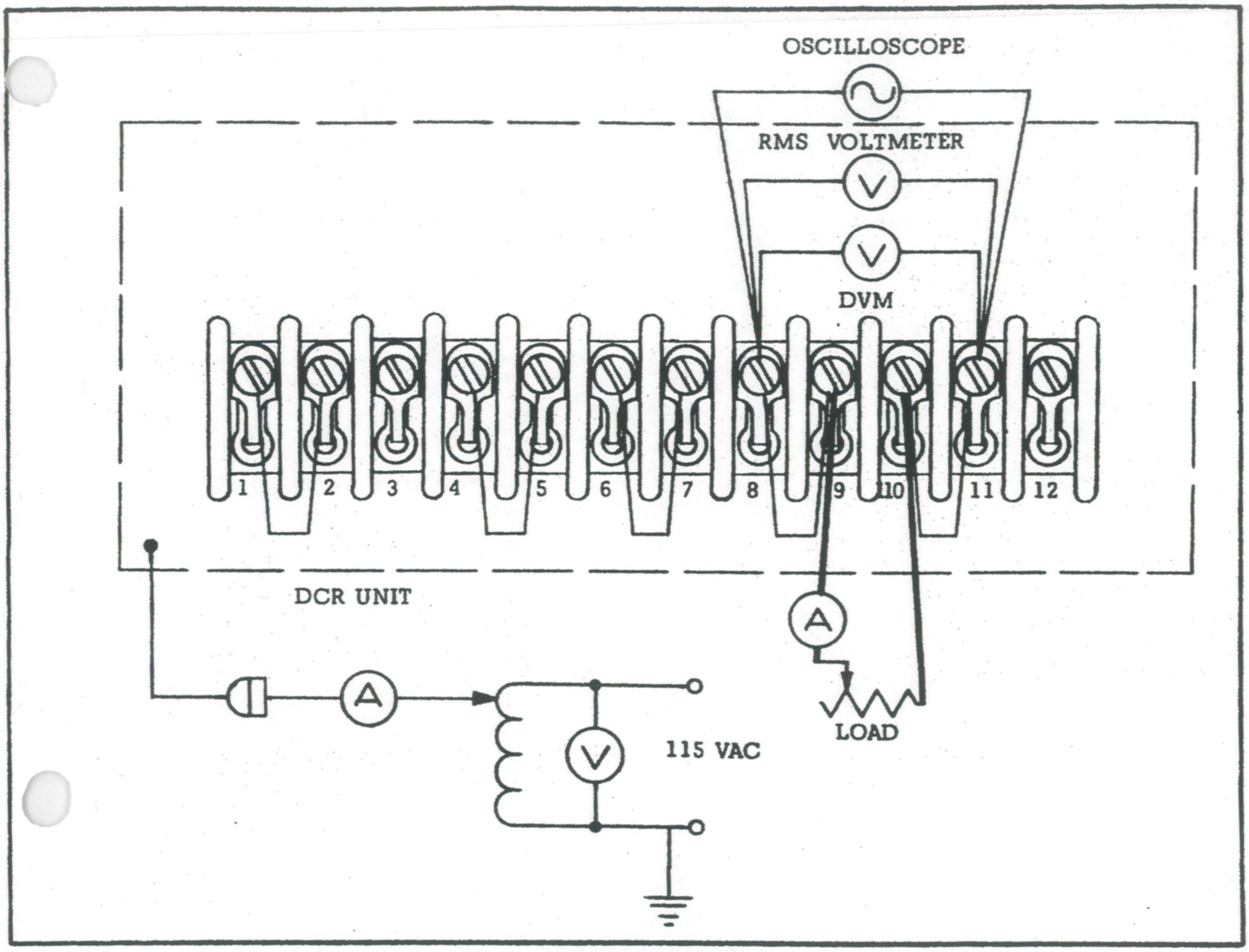


Figure 5-5. Performance Test Setup

	DCR MODEL				
	40-20A	60-13A	80-10A	150-5A	300-2.5A
Voltage Mode High End Set Point (Vdc)	40 ± .2	60 ± .3V	80 ± .3	150 ± .5	300 ± .8
Current Mode High End Set Point (Adc)	25 ± .1	16 ± .1	12.5 ± .1	6.25 ± .1	3.2 ± .1

Table 5-2. Calibration Data

the output terminals and then reset breaker to ON.

b. Rotate CUR. ADJUST AMPS. control fully clockwise. Output current should be equal to that given in Table 5 - 2 for the applicable model. Adjust using potentiometer R32 if required.

c. Turn CUR. ADJUST AMPS. control fully counterclockwise. Output should be 0 ± .1A. If necessary, adjust using potentiometer R30.

d. Repeat steps b. and c. in sequence, until high and low end settings are as specified.

e. Connect a sensitive voltmeter across resistor R76. Indication should be between 4.15 and 4.25 Vdc when measured under condition b. above. If required, adjust using potentiometer R77. CURRENT MODE lamp should be glowing. Set unit breaker to OFF.

5-13. PERFORMANCE TESTING.

5-14. Sensitive instruments, like the DCRA, require vigorous testing methods if a true performance evaluation is to be made. Wherever possible use twisted leads with test equipment to reduce stray pick-up. At the power-supply terminal board, these leads must be firmly held by the terminal screws. Alligator clips and similar types of connectors are not suitable. Note that the output specifications are applicable at rear terminals only. (Front-panel binding posts sometimes introduce errors, which, although small, are sufficient to influence measurements.) In addition, grounding techniques in which more than one device in the setup is grounded may introduce extraneous ripple that, although unrelated to the power-supply-output ripple, is displayed on the test oscilloscope.

5-15. VOLTAGE-MODE REGULATION AND RIPPLE. To check voltage-mode regulation and ripple, proceed as follows:

a. Connect a sensitive differential or digital voltmeter and an RMS meter across unit output terminals. (See Figure 5 - 5 for test setup.) If a differential voltmeter is used, set internal voltage equal to unit's rated output. Use an autotransformer with a current rating that exceeds the maximum unit input current (Table 1 - 1).

Note

Input devices such as autotransformers or line regulators can distort the input wave sufficiently to adversely affect performance measurements.

	DCR MODEL				
	40-20A	60-13A	80-10A	150-5A	300-2.5A
I rated 30 ° C (Adc)	23	15	11.5	5.75	2.88
Regulation, Volt. Mode (mV)	60	90	120	225	450
Ripple, Volt. Mode (mV)	180	270	360	700	1400
Transient Deviation (V)	1.2	1.8	2.4	4.5	9
I rated 55°C (Adc)	20	13	10	5	2.5
Max. Compliance Voltage (Vdc)	38.0	57.0	75.0	140.0	280.0
Regulation, Cur. Mode (converted to mV)	4.5	3.5	3.5	2.5	2.5

Table 5-3. Performance Test Data.

b. Apply 103.4 Vac to input, and then set unit circuit breaker to ON.

c. Rotate CUR. ADJUST AMPS. control clockwise.

d. Use COARSE and FINE VOLTAGE ADJUST controls to obtain rated output.

e. Simultaneously increase input voltage and load until voltage is 126.5 Vac and load is drawing rated current at 30°C. (See Table 5 - 3). Output voltage should not deviate more than specified in Table 5 - 3, nor should the ripple be more than that specified.

f. Disconnect test set-up.

5-16. TRANSIENT RESPONSE. Test transient response as follows:

a. Connect an oscilloscope across output terminals.

b. Set unit circuit breaker to ON, and then rotate both COARSE VOLTAGE ADJUST and CUR. ADJUST AMPS. controls fully clockwise.

c. Apply half load, and then abruptly apply full load (or go from full load to half load). Typical output deviation is listed in Table 5 - 3. Return to steady state should be within 30 milliseconds (typical).

Note

Load switching time should be less than 3 milliseconds.

d. Discontinue test by opening circuit breaker.

5-17. CURRENT-MODE REGULATION. To check current-mode regulation, proceed as follows:

a. At no load, adjust output to maximum rated voltage and set CUR. ADJUST AMPS. control for rated current at 55°C (Table 5 - 3). Open unit circuit breaker.

b. Connect a 0.1 ohm, 50 W sensing resistor in series with a variable load and across the output terminals.

c. Apply 103.4 Vac to input and then close unit circuit breaker. Apply load until crossover to current mode occurs. (CURRENT MODE light glows brightly and output voltage drops to about that value specified in Table 5 - 3, max. compliance voltage.)

d. Connect a differential voltmeter across the sensing resistor, set internal voltage to 10 mV, and note indication.

e. Simultaneously increase input voltage and load until input voltage is 126.5 Vac and compliance voltage is 0. Note indications on differential voltmeter. Change in voltmeter reading should not exceed that given in Table 5-3.

SECTION VI

REPLACEMENT PARTS LIST

6-1. GENERAL.

6-2. This section provides a replacement parts list for the DCRA 800-Watt Series. The list is keyed both to the parts locating photographs (Figure 5-1, and 5-2), and to the schematic diagram, Figure 5-4.

6-3. MANUFACTURER CODE.

6-4. The column headed MANUFACTURER CODE contains a listing of letter designators, keyed to the tabulation which follows, and provides the means of ascertaining from whom a particular part may be purchased.

AB	Allen Bradley Company
AX	Aerovox Corp.
CB	Centralab, Div.of Globe Union,Inc.
CD	Cornell-Dubilier
CS	Clarostat Manufacturing Co.,Inc.
EFJ	E.F.Johnson Company
FC	Fairchild Semidonductor
GE	General Electric Co.
HA	Hughes Aircraft Co.
HM	Heinemann Electric Co.
IRC	International Resistance Co.
MA	Motorola Semiconductor Products
RCA	Radio Corporation of America
RN	Rotron Manufacturing Company
RDM	Radio Material Co.,Div. P.R.Mallory
RS	Raytheon Co., Sorensen Operation
RT	Raytheon Company
SG	Sage Electronics Corp.
SP	Sprague Electric Company
ST	Solitron Devices, Incorporated
TI	Texas Instruments
WH	Westinghouse Electric Corp.
WL	Ward Leonard Electric Co.

6-5 MODIFICATION MODELS.

6-6. Replacement parts for factory modified units, i.e., 220/230 Vac input conversion, are identical to those for standard models except for those parts listed in Table 6-2.

6-7. ORDERING PARTS.

6-8. When ordering parts from Raytheon Co., Sorensen Operation, include manufacturer's part number, the Sorensen part number and the unit model number. Address orders to:

Raytheon Company
Sorensen Operation
Richards Avenue
Norwalk, Connecticut 06856

REF DES	DCR 800-WATT MODELS 40V	60V	80V	150V	300V	DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER PART NUMBER	CODE
B1	X	X	X	X	X	Fan	91-1000-2	Muffin	RN
C1 a,b	X					Cap., 22.4 mF, 50 Vdc	24-2299-7	24-2299-7	RS
		X				Cap., 14 mF, 75 Vdc	24-1034-2	24-1034-2	RS
			X			Cap., 6.1 mF, 100 Vdc	24-2526-6	24-2526-6	RS
				X		Cap., 3.7 mF, 200 Vdc	24-2467-4	24-2467-4	RS
					X	Cap., 880 µF, 350 Vdc	24-2470-2	24-2470-2	RS
C5	X	X	X	X	X	Cap., 470 nF, 200 Vdc	24-2409-17	V146xR	AX
C6	X	X	X	X	X	Cap., 1.25 µF, 200 Vdc	24-2409-22	VI46xR	AX
C7,18	X	X	X	X	X	Cap., 2 µF, 200 Vdc	24-2409-21	VI46xR	AX
C8,10,24,25,48	X	X	X	X	X	Cap., 100 nF, 200 Vdc	24-2409-13	VI46xR	AX
C9	X	X	X	X	X	Cap., 22 nF, 200 Vdc	24-2409-9	VI46xR	AX
C11	X	X	X	X	X	Cap., 50 µF, 25 Vdc	24-2286-5	TVA Series	SP
C12,13,23	X	X	X	X	X	Cap., 25 µF, 25 Vdc	24-2286-4	TVA Series	SP
C14,16	X	X	X	X	X	Cap., 100 µF, 15 Vdc	24-2285-2	TVA Series	SP
C15,19	X	X	X	X	X	Cap., 10 nF, 200 Vdc	24-2409-7	VI46xR	AX
C17	X	X	X	X	X	Cap., 10 µF, 25 Vdc	24-2286-3	TVA Series	SP
C20,21	X	X	X	X	X	Cap., 500 µF, 50 Vdc	24-2287-9	45D	SP
C22 a,b					X	Cap., 20 nF, 900 Vac	24-026	U02GMV	RDM
C26*,27*	X	X	X	X	X	Cap., 330 nF, 400 Vdc	24-2411-16	V146R	AX
C28	X	X	X	X	X	Cap., 2.0 µF, 330 Vac	24-369	KS3020-1A	CD
C29,38*,39*	X	X	X	X	X	Cap., 50 nF, 500 Vdc	24-2010	05 TID	CB
C30,31	X	X	X	X		Cap., 330 nF, 400 Vdc	24-2411-16	V146xR	AX
					X	Cap., 47 nF, 600 Vdc	24-2410-11	V146xR	AX
C32,33,34,35	X	X	X			Cap., 50 nF, 500 Vdc	24-2010	V146xR	CB
				X		Cap., 10 nF, 1000 Vdc	24-2011	DD103	CB
C37	X	X	X	X		Cap., 220 nF, 200 Vdc	24-2409-15	V146AR	AX
					X	Cap., 220 nF, 400 Vdc	24-2411-15	V146AR	AX
C40,41,46,47	X	X	X	X		Cap., 50 nF, 500 Vdc	24-2010	05 TID	CB
CB1*	X	X	X	X	X	Circuit Breaker	92-340	AM 12-25	HM
CR1-4	X					Rectifier	26-173-4	368D	WH
		X				Rectifier	26-173-5	368F	WH
			X			Rectifier	26-173-6	368H	WH
				X		Rectifier	26-173-8	368M	WH
					X	Rectifier	26-149-6	A10M	GE

* For modified units, refer to Table 6-2.

Table 6-1. Replacement Parts List (Sheet 1 of 5)

REF DES	DCR 800-WATT MODELS 40V	60V	80V	150V	300V	DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER PART NUMBER	CODE
CR6,9,23,37	X	X	X	X	X	Rectifier	26-158-1	CER68	ST
CR7,8*	X	X	X	X	X	Rectifier	26-178-5	E30Cx7	GE
CR12,13,34,35	X	X	X	X	X	Rectifier	26-158-2	CER68	ST
CR14-21,30,33, 40	X	X	X	X	X	Rectifier	26-1017	RD 5637/9119	RT
CR36	X	X	X	X	X	Rectifier	26-211	1N750A	MA
CR38,41	X	X	X	X	X	Rectifier	26-206	1N753	MA
CR39	X	X	X	X	X	Rectifier	26-223	1N746 Hughes	HA
DS1	X	X	X	X	X	Lamp	42-301	NE-51	GE
DS2	X	X	X	X	X	Lamp	42-315	1829	GE
DS3	X	X	X	X	X	Lamp	42-341	1302	GE
L1	X					Choke	127-1633	127-1633	RS
		X				Choke	127-1632	127-1632	RS
			X			Choke	127-1630	127-1630	RS
				X		Choke	127-1631	127-1631	RS
					X	Choke	127-1664	127-1664	RS
L2*	X	X	X	X	X	Choke	127-1688	127-1668	RS
M1	X					Ammeter, 0-30 Adc	94-433-12	94-433-12	RS
		X				Ammeter, 0-20 Adc	94-433-5	94-433-5	RS
			X			Ammeter, 0-15 Adc	94-433-10	94-433-10	RS
				X		Ammeter, 0-8 Adc	94-433-9	94-433-9	RS
					X	Ammeter, 0-3 Adc	94-433-16	94-433-16	RS
M2	X					Voltmeter, 0-50 Vdc	94-549-4	94-549-4	RS
		X				Voltmeter, 0-80 Vdc	94-549-9	94-549-9	RS
			X			Voltmeter, 0-100 Vdc	94-549-4	95-549-4	RS
				X		Voltmeter, 0-200 Vdc	94-549-6	94-549-6	RS
					X	Voltmeter, 0-400 Vdc	94-549-12	94-549-12	RS
Q1,2,4,5,7,9, 10,17,21,22, 23,24	X	X	X	X	X	Transistor, NPN	18-144	2N3641	FC

* For modified units, refer to Table 6-2.

Table 6-1. Replacement Parts List (Sheet 2 of 5)

REF DES	DCR 800-WATT MODELS 40V	60V	80V	150V	300V	DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER PART NUMBER	CODE
Q3,6,11-14	X	X	X	X	X	Transistor, PNP	18-143	2N3638	FC
Q8	X	X	X	X	X	Transistor, UJ	18-097	2N1671A	GE
Q15,16	X	X	X	X	X	Transistor, NPN	18-125-2	2N2926	GE
Q19	X	X	X	X	X	Transistor, NPN	18-142	40312	RCA
Q25	X	X	X	X	X	Transistor, NPN	18-145	RT 9343	RT
R1	X					Resistor, 75 ohm, 100 W	27-847	100F75	WL
		X				Resistor, 150 ohm, 100 W	27-1034	100F150	WL
			X			Resistor, 250 ohm, 100 W	27-831	100F250	WL
				X		Resistor, 1k ohm, 100 W	27-837	100F1000	WL
					X	Resistor, 4k ohm, 100 W	27-1059	100F4000	WL
R2	X					Resistor, 25 ohm, 100 W	27-889	100F25	WL
		X				Resistor, 50 ohm, 100 W	27-856	100F50	WL
			X			Resistor, 75 ohm, 100 W	27-847	100F75	WL
				X		Resistor, 250 ohm, 100 W	27-831	100F250	WL
					X	Resistor, 1.5k ohm, 100 W	27-1030	100F1500	WL
R4	X					Resistor, 33m ohm	190-3393	190-3393	RS
		X				Resistor, 50m ohm	190-3282	190-3282	RS
			X			Resistor, 65m ohm	190-3596	190-3596	RS
				X		Resistor, 130m ohm	190-3597	190-3597	RS
					X	Resistor, 260m ohm	190-3382	190-3392	RS
R6,7*	X	X	X	X	X	Resistor, 500m ohm, 50 W	27-1050	27-1050	RS
R9,26,34,59	X	X	X	X	X	Resistor, 4.7k ohm, 1/2 W	27-107	EB 4721	AB
R10,49,54	X	X	X	X	X	Resistor, 22k ohm, 1/2 W	27-142	EB 2231	AB
R11,12,55	X	X	X	X	X	Resistor, 2.7k ohm, 1/2 W	27-174	EB 2721	AB
R13	X	X	X	X	X	Resistor, 68k ohm, 1/2 W	27-143	EB 6831	AB
R14,18,23,51	X	X	X	X	X	Resistor, 2.2k ohm, 1/2 W	27-152	EB 2221	AB
R15	X	X	X	X	X	Resistor, 5.6k ohm, 1/2 W	27-1112	EB 5625	AB
R16,19,40	X	X	X	X	X	Resistor, 10k ohm, 1/2 W	27-133	EB 1031	AB
R17	X	X	X	X	X	Resistor, 1.8k ohm, 1/2 W	27-176	EB 1821	AB
R20	X	X	X	X	X	Resistor, 680 ohm, 1/2 W	27-156	EB 6811	AB
R21	X	X	X	X	X	Resistor, 6.8k ohm, 1/2 W	27-185	EB 6821	AB
R22,24,35,37, 64,65,66,74,75	X	X	X	X	X	Resistor, 1k ohm, 1/2 W	27-103	EB 1021	AB
R25	X	X	X	X	X	Resistor, 220 ohm, 1/2 W	27-101	EB 2211	AB
R27	X	X	X	X	X	Resistor, 390 ohm, 1/2 W	27-1109	EB 3911	AB
R28,29,36	X	X	X	X	X	Resistor, 47 ohm, 1/2 W	27-181	EB 4701	AB
R30	X	X	X	X	X	Pot., 100 ohm, 2 W	29-449		CS

* For modified units, refer to Table 6-2.

Table 6-1. Replacement Parts List (Sheet 3 of 5)

REF DES	DCR 800-WATT MODELS 40V	60V	80V	150V	300V	DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER PART NUMBER	CODE
R31,46	X	X	X	X	X	Pot., 150 ohm, 2 W	29-391	Type 43	CS
R32	X	X	X	X	X	Pot., 5k ohm, 2 W	29-476	Type 43	CS
R33	X	X	X	X	X	Resistor, 100 ohm, 1/2 W	27-173	EB 1011	AB
R38,79	X	X	X	X	X	Resistor, 560 ohm, 1/2 W	27-1103	EB 5611	AB
R39,72	X	X	X	X	X	Resistor, 330 ohm, 1/2 W	27-102	EB 3311	AB
R41	X	X	X	X	X	Resistor, 475 ohm, 1/2 W	28-1146	CECTO	IRC
R43	X	X	X	X	X	Resistor, 1k ohm, 1 W	27-297	GB 1025	AB
R44	X	X	X	X	X	Pot., 2k ohm, 2 W	29-407	Type 43	CS
R45	X	X	X	X	X	Pot., 3k ohm, 2 W	29-408	Type 43	CS
R47	X	X				Pot., 2k ohm, 2 W	29-407	Type 43	CS
			X	X	X	Pot., 1k ohm, 2 W	29-406	Type 43	CS
R48,71	X	X	X	X	X	Resistor, 470 ohm, 1/2 W	27-166	EB 4711	AB
R50	X	X	X	X	X	Resistor, 180 ohm, 1/2 W	27-190	EB 1811	AB
R52	X	X	X	X	X	Resistor, 2k ohm, 1/2 W	27-105	EB 2021	AB
R53	X	X	X	X	X	Resistor, 120 ohm, 1/2 W	27-1107	EB 1211	AB
R56	X					Resistor, 4.7k ohm, 5 W	28-1150	1500S4700-5	SG
		X				Resistor, 6.8k ohm, 5 W	28-1151	1500S6800-5	SG
			X			Resistor, 8.2k ohm, 5 W	28-1152	1500S8200-5	SG
				X		Resistor, 15k ohm, 5 W	28-1154	1500S15000-5	SG
					X	Resistor, 29k ohm, 5 W	28-1183	1500S29000-5	SG
R57	X	X	X	X	X	Resistor, 900 ohm, 3 W	28-1153	1500S900-5	SG
R62	X	X	X	X	X	Resistor, 390 ohm, 1 W	28-703	GB 3911	AB
R63	X	X	X	X	X	Resistor, 1.2k ohm, 1 W	28-727	GB 1225	AB
R67	X	X	X	X	X	Resistor, 680 ohm, 1 W	28-701	GB 6811	AB
R68	X	X	X	X	X	Pot., 1k ohm, 2 W	29-406	Type 43	CS
R70 a,b					X	Resistor, 560 ohm, 1 W	28-717	GB 5611	AB
R73	X	X	X	X	X	Resistor, 5.1k ohm, 2 W	27-344	HB 5125	AB
R76	X	X	X	X	X	Resistor, 100 ohm, 1/2 W	28-1203	CEC-TO	IRC
R77	X	X	X	X	X	Pot., 50 ohm, 2 W	29-467	Series 110	IRC
R78	X	X	X	X	X	Resistor, 22 ohm, 1/2 W	27-153	EB 2201	AB
S1	X	X	X	X	X	Thermostat, 195 $\pm$5°F	91-1286	20700F	TI
T1*	X					Transformer	126-2623	126-2623	RS
		X				Transformer	126-2620	126-2620	RS
			X			Transformer	126-2621	126-2621	RS
				X		Transformer	126-2622	126-2622	RS
					X	Transformer	126-2700	126-2700	RS

* For modified units, refer to Table 6-2.

Table 6-1. Replacement Parts List (Sheet 4 of 5)

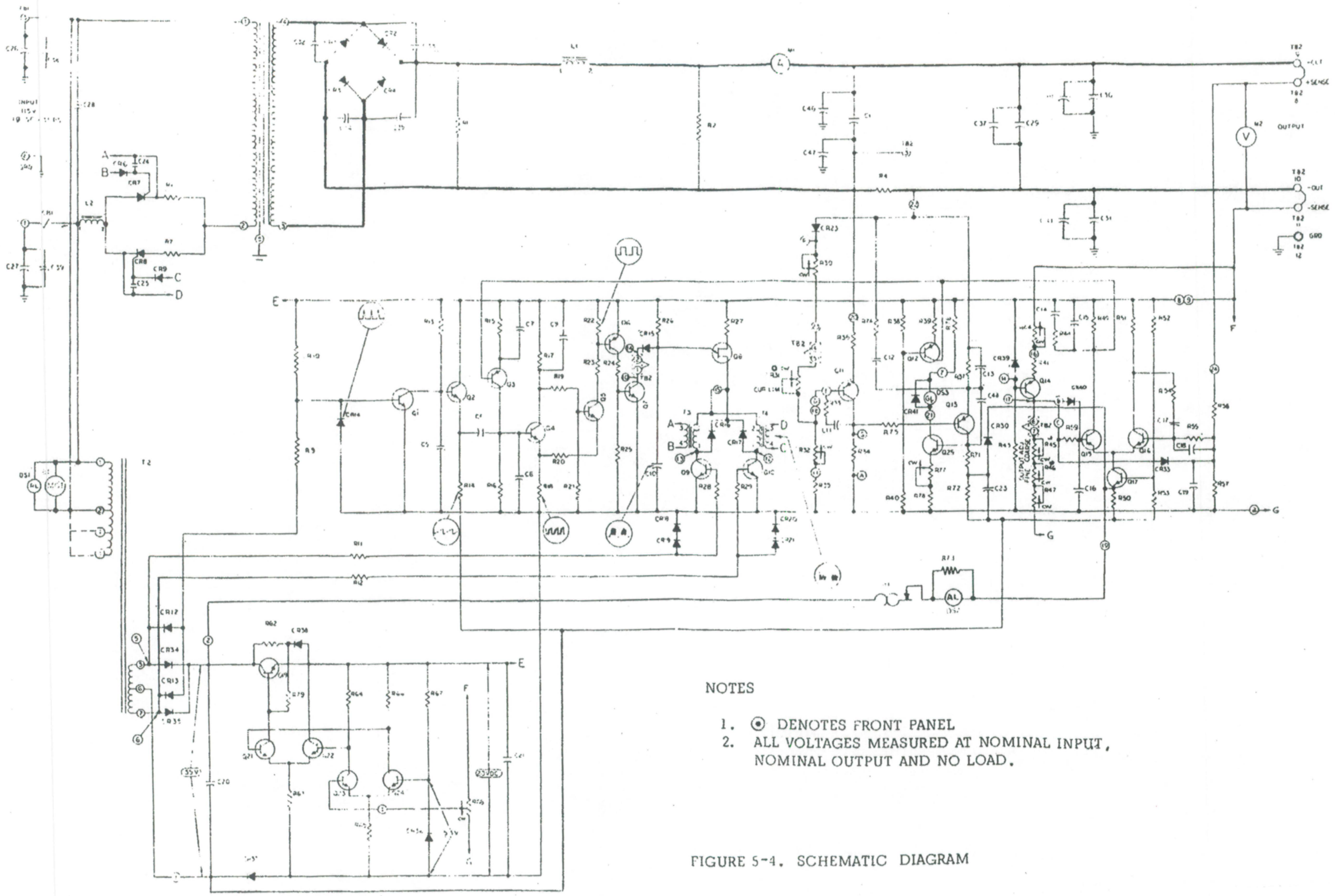
REF DES	DCR 800-WATT MODELS					DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER	
	40V	60V	80V	150V	300V			PART NUMBER	CODE
T2*	X	X	X	X	X	Transformer	126-2627	126-2627	RS
T3,4	X	X	X	X	X	Transformer	126-2570	126-2570	RS
XDS1	X	X	X	X	X	Lamp Holder, Red	42-383	147-1142-1	EFJ
XDS2	X	X	X	X	X	Lamp Holder, Amber	42-322	147-1142-2	EFJ
XDS3	X	X	X	X	X	Lamp Holder, Green	43-341	147-1142-3	EFJ
Front Terminals	X	X	X	X	X		4-503-2	DF-30RC	SE
Rear Terminals	X	X	X	X	X		A90-3703	12-141-4	JO
Rubber Feet	X	X	X	X	X		91-214	91-214	RS

* For modified units, refer to Table 6-2.

Table 6-1. Replacement Parts List (Sheet 5 of 5)

REF DES	DCR 800-WATT MODELS					DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER	
	40V	60V	80V	150V	300V			PART NUMBER	CODE
C26,27,38,39	X	X	X	X	X	Not used			
CB1	X	X	X	X	X	Circuit Breaker	92-339	AM 12-12	HM
CR7,8	X	X	X	X	X	Rectifier	26-178-7	CBO EX7	GE
L2	X	X	X	X	X	Choke	127-1750	127-1750	RS
R6,7	X	X	X	X	X	Resistor, 1.5k ohm, 110 W	27-1069	RIBFLEX TT201	WL
T1	X					Transformer	126-2837	126-2837	RS
		X				Transformer	126-2838	126-2838	RS
			X			Transformer	126-2839	126-2839	RS
				X		Transformer	126-2840	126-2840	RS
					X	Transformer	126-2841	126-2841	RS
T2	X	X	X	X	X	Transformer	126-2848	126-2848	RS

Table 6-2. Difference Data, Modified Units



NOTES

1. ⊙ DENOTES FRONT PANEL
2. ALL VOLTAGES MEASURED AT NOMINAL INPUT, NOMINAL OUTPUT AND NO LOAD.

FIGURE 5-4. SCHEMATIC DIAGRAM